PB85-242519

Field Agricultural Runoff
Monitoring (Farm) Manual

(U.S.) Environmental Research Lab., Athens, GA

Jun 85

U.S. Department of Commerce
National Technical Information Service
NTIS

United States
Environmental Protection
Agency

Environmental Research
Laboratory
Athens GA 30613

EPA/600/3-85/043
June 1985

PB85-242519

Research and Development

EPA

Field Agricultural Runoff Monitoring (FARM) Manual

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(Please read Instructions on the reverse before completing)

1. REPORT NO.
EPA/600/3-85/043

2.

3. RECIPIENT'S ACCESSION NO.
PB85 242519/AS

4. TITLE AND SUBTITLE
FIELD AGRICULTURAL RUNOFF MONITORING (FARM) MANUAL

5. REPORT DATE
June 1985

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)
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8. PERFORMING ORGANIZATION REPORT NO.

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Environmental Research Laboratory, USEPA, Athens GA
*Anderson-Nichols, Inc., Palo Alto CA 94303
**Computer Sciences Corporation, Environmental Research
Laboratory, Athens GA 30613

10. PROGRAM ELEMENT NO.
ACBE1A

11. CONTRACT/GRANT NO.

12. SPONSORING AGENCY NAME AND ADDRESS
Environmental Research Laboratory - Athens, GA
Office of Research and Development
U.S. Environmental Protection Agency
Athens, GA 30613

13. TYPE OF REPORT AND PERIOD COVERED
Final, 9/83 - 4/85

14. SPONSORING AGENCY CODE
EPA/600/01

15. SUPPLEMENTARY NOTES

16. ABSTRACT

A field monitoring protocol was developed to provide comprehensive guidelines for developing pesticide runoff data bases for use in conducting environmental exposure assessments as part of the registration process conducted by EPA's Office of Pesticide Programs. These data bases must be carefully planned to insure that important measurements are made and that both appropriate quality and quantity data are obtained for a representative agronomic location and management scenario. Detailed guidance is provided, therefore, on site selection, experimental design, data requirements, sampling procedures, equipment, quality assurance planning, data base management, data analysis, and exposure assessment modeling.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

18. DISTRIBUTION STATEMENT
RELEASE TO PUBLIC

19. SECURITY CLASS (This Report)
UNCLASSIFIED

20. SECURITY CLASS (This page)
UNCLASSIFIED

21. NO. OF PAGES
249

22. PRICE

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

EPA/600/3-85/043
June 1985

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FOREWORD

As environmental controls become more costly to implement and the penalties of judgement errors become more severe, environmental quality management requires more efficient management tools based on greater knowledge of the environmental phenomena to be managed. As part of this laboratory's research on the occurrence, movement, transformation, impact, and control of environmental contaminants, the Technology Development and Applications Branch develops management and engineering tools to help pollution control officials achieve water quality goals through watershed management.

Because of the toxicity and persistence of many pesticides and their extensive use in modern agriculture, the runoff losses of these chemicals from agricultural fields and the resulting concentrations in surface water bodies is an environmental concern. During the 1970s, several research studies of pesticide runoff from fields were conducted by the U.S. EPA to provide data for developing and testing nonpoint source runoff models.

Experience gained in this research prompted the development of this field runoff protocol manual for use primarily by EPA's Office of Pesticide Programs in assisting registrants in meeting data collection needs. Field data collection is part of the pesticide registration process in which an exposure assessment is performed to estimate potential exposure to humans and other organisms resulting from the agricultural, silvicultural, and other applications of pesticides. The manual is intended to assist in the development of consistent data bases for exposure assessment modeling thus producing a cost-effective procedure for both EPA and the registrant.

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ABSTRACT

A field monitoring protocol was developed to provide comprehensive guidelines for developing pesticide runoff data bases for use in conducting environmental exposure assessments as part of the registration process conducted by the Office of Pesticide Programs (OPP). These data bases must be carefully planned to insure that important measurements are made and that both the appropriate quality and quantity of data are obtained for a representative agronomic location and management scenario. Detailed guidance is provided, therefore, on site selection, experimental design, data requirements, sampling procedures, equipment, quality assurance planning, data base management, data analysis, and exposure assessment modeling.

This report was developed in part (Sections 2, 5 and 6) by contract 68-03-3116 to Anderson Nichols Co., Inc., Palo Alto, CA, under the sponsorship of the U.S. Environmental Protection Agency. The report covers a period from September 1983 to April 1985, and work was completed as of May 1985.

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ACKNOWLEDGMENTS

The authors express sincere appreciation to the technical reviewers for their helpful suggestions. They included Dr. J. L. Baker, Iowa State University; Dr. R. W. Holst, U.S. Environmental Protection Agency; Dr. G. W. Langdale, U. S. Department of Agriculture; M. N. Lorber, U.S. Environmental Protection Agency; Dr. G. R. Oliver, Dow Chemical Company; and Dr. D. D. Sumner, Ciba-Geigy Corporation.

The authors gratefully acknowledge Annie Smith's efforts in synthesizing a typed original first draft from our many pages of pencilled notes, and for persevering through long hours of corrections leading to the final deadlines. A similar thanks is extended to Bob Ryans for his very able editorial and photographic assistance.

Acknowledgement is extended to T. Prather, B. Bartell, S. Hodge, and R. Moon of the Computer Sciences Corporation for drafting many of the figures.

We thank Drs. E. D. Law and J. L. Chesness, University of Georgia, for supplying photographs of the electrostatic sprayer and chemigation system.

SECTION 1

INTRODUCTION

1.1 STATEMENT OF PROBLEM

As part of its mandate under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), the U. S. Environmental Protection Agency is required to register and approve pesticide compounds before they are released for widespread use in the United States. FIFRA requires that data on toxicity, health effects, etc. be submitted to the Agency in support of the registration of a pesticide. As part of the registration process, an exposure assessment is performed to estimate environmental exposures of chemicals to humans and other organisms resulting from the applications of pesticides for agricultural, silvicultural, and other uses. Because of the toxicity and persistence of many pesticides and their extensive use in modern agriculture, the runoff losses of pesticides from agricultural fields and the resulting concentrations in surface water bodies is a major environmental concern.

Pesticide runoff problems are associated with nonpoint source pollution because agricultural chemicals are of widespread use in our modern society and management of soil and water resources from agricultural systems influences the use, fate, and transport of chemicals. Evaluation of pesticide risk (probability of damage) to the environment by agricultural runoff requires an understanding of pesticide properties and agronomic practices, and a detailed description of the hydrologic cycle. The system to be examined can consist of a single field, a watershed, or a river basin. Each type of system has definite physical boundaries and its response to pesticide runoff is determined by the combination of physical characteristics of soils, topography, geology, vegetation and drainage networks (Bailey and Swank, 1983). Inputs to the system (Figure 1.1) include both natural inputs (i.e., uncontrolled inputs such as weather conditions) and man-induced inputs (i.e., chemical application and management practices). In general, the field or watershed produces pesticide runoff loadings to water bodies depending on the relative timing of applications and storm events, soil and chemical characteristics, topographic and geologic characteristics, and agronomic and engineering practices (Donigian et al., 1985). After pesticide application, the chemical is subjected to numerous physical, chemical, and biological processes that transform, and transport the compound as the hydrologic cycle interacts with the soil-plant-pesticide system.

Natural Inputs
Climatic
- Precipitation — rain, snow
- Evapotranspiration
- Temperature
- Solar Radiation
- Wind
- Relative Humidity

Field System
- Soils
- Topography
- Geology
- Vegetation
- Drainage network

Field Response
- Surface Runoff

Man's Inputs
Seasons

Spring –	Tillage Starter Fertilizer Application Pre-emergence Pesticide Application Plant Crop Post-emergence Pesticide Application
Summer –	Cultivation Secondary Fertilizer Application Foliar Pesticide Application
Fall –	Harvest Crop

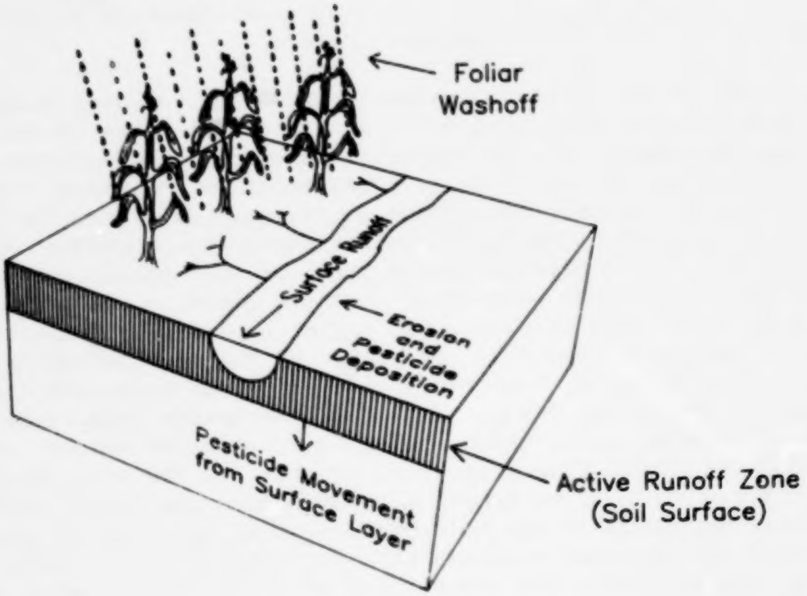
Foliar Washoff
Surface Runoff
Erosion and Pesticide Deposition
Pesticide Movement from Surface Layer
Active Runoff Zone (Soil Surface)

FIGURE 1.1. Schematic of field runoff situation

1.2 PURPOSE OF MANUAL

The objective of this work was to develop a standard methodology for the collection of pesticide runoff data for use by the EPA's Office of Pesticide Programs (OPP), as well as the pesticide industry. Runoff data are required to conduct exposure assessments when new pesticides are submitted for registration, when new uses are proposed for existing pesticides, and when existing pesticides are being re-evaluated because of concern for human health or the environment.

A standard data collection procedure is of greater importance today because of the wide-spread use of modeling to evaluate the environmental exposure and risks of a specific pesticide. Environmental exposure models require certain essential data and the observed data base must address this need.

The suggested field and laboratory measurements discussed in this manual are intended to provide guidance for conducting either detailed research investigations or information for use in model calibration and application. Extension of measured data through modeling is considered a major element of exposure/risk assessments. The data collected from these studies can, therefore, be used for conducting exposure/risk assessments. Specific monitoring requirements (e.g., rainfall data, pan evaporation data, etc.) will depend on the detailed study objectives, pesticide application mode (e.g., foliar versus soil applied), and the model of choice.

Field studies involve tradeoff between costs and relative values of information obtained. Table 1.1 provides some general guidance on the kinds of information normally needed for the two most common objectives in field runoff studies, i.e., research and development and model calibration.

TABLE 1.1. FIELD RUNOFF STUDY REQUIREMENTS

Factors or Measurements	Research and Development	Model Calibration/ Exposure Assessment
Site selection based on crop, land and chemical use area	X	X
Area of Field	X	X
Meteorological		
Precipitation depth		
Interval	X	X[a]
Evaporation	X	X[b]
Solar radiation	X	X[b]
Air temperature	X	X[b]
Relative humidity	X	X[b]
Wind speed/direction	X	X[b]

TABLE 1.1 (Cont'd). FIELD RUNOFF STUDY REQUIREMENTS

Factors or Measurements	Research and Development	Model Calibration/ Exposure Assessment
Total wind	X	X[b]
Soil Characteristics		
Series identification	X	X
Hydrologic group	X	
Texture	X	
Organic carbon	X	X
Bulk density	X	
pH	X	
Temperature	X	
Moisture	X	
Infiltration rate	X	
Erodibility	X	X[b]
Sampling Network Design	X	X
Quality Assurance Plan	X	X
Pesticide Application Rate and Distribution on Plant Residue-Soil	X	X
Runoff (for each event)		
Total volume	X	X
Sediment yield	X	X
Pesticide Runoff Sampling (dissolved and sorbed)		
Inter-event	X	
Whole-event		X[c]
Runoff Sediment Characterization		
Particle size analysis	X	
Organic carbon	X	
Cation exchange capacity	X	
Enrichment ratio	X	
Soil Sampling after Runoff Events		
Individual sites	X	
Composite		X
Mass of Pesticide in Precipitation	X	
Land/Crop Management (i.e., USLE factors)	X	X[d]

TABLE 1.1 (Cont'd). FIELD RUNOFF STUDY REQUIREMENTS

Factors or Measurements	Research and Development	Model Calibration/ Exposure Assessment
Canopy		
Percent cover	X	X
Leaf area index	X	
Pesticide foliar washoff	X	X
Temperature	X	
Plant uptake	X	
Crop yield	X	
Residue remaining after harvest	X	
Pesticide Residue in Harvested Material and Post-Harvest Crop Residue	X	
Field Operations Record Keeping	X	X
Pesticide Residue in Crop Cover at Application Time (Conservation Tillage)	X	X
Data Storage	X	X
Pesticide Degradation Rates		
Soil	X	X
Foliar (if foliar applied)	X	X
Volatilization		
Soil	X	X[b]
Foliar (if foliar applied)	X	X[b]
Pesticide Sorption Partition Coefficient (K_p)	X	X[e]

[a] Specific interval (i.e., hourly, daily) is model dependent.

[b] Specific combinations are used in various models.

[c] Composited sample. Some models predict hydrograph dynamics; most predict storm totals.

[d] These values can be estimated.

[e] Value can be either measured for field soils or estimated based on soil organic carbon content.

Field runoff research studies conducted by EPA and cooperators during the 1970s provide excellent reference material (Smith et al., 1978; Johnson and Baker, 1982 and 1984; Ellis et al., 1977). Other excellent sources of reference include the USDA (1979), Southern Weed Science Society (1977), and Wauchope (1985, in preparation). These reports can be obtained through USDA and the National Technical Information Service (NTIS) in Springfield, VA.

The research studies conducted jointly by EPA, USDA, and several universities were designed to develop and test pesticide runoff loading models. These studies provided data to develop the first EPA simulation model designed to mathematically describe nonpoint source pollution (Crawford and Donigian, 1973). This modeling effort was extended with the development and testing of the Agricultural Runoff Model (Donigian and Crawford, 1976; Donigian et al., 1977). Several runoff models have been tested on these data bases and include the Hydrological Simulation Program--FORTRAN (Johanson et al., 1984; Donigian et al., 1984) and CREAMS--Chemicals Runoff and Erosion from Agricultural Management Systems developed by USDA (1980). Recent field research and mathematical model development have provided a mechanism to develop detailed exposure/risk assessments for pesticides. The components required to effectively link observed field runoff data and pesticide runoff models (for conducting exposure/risk assessment) are listed in Figure 1.2.

The information presented in this manual is designed to provide the user with a detailed information framework for developing and designing components of a pesticide runoff study based on current understanding. The design of such studies will provide the Agency and the registrant with sufficient information to conduct an exposure/risk assessment for the registration process. Specific recommendations for sampling, instrumentation needs, sample processing, and data analysis are provided.

- Select a site from cropping, land, and chemical use characteristics.
- Develop experimental and quality assurance design network.
- Monitor relevant soils, crop and climatic characteristics and pesticide volatilization transport/transformation properties to obtain mass balance.
- Analyze and format collected data into a systematic data set.
- Calibrate model to observed pesticide runoff data.
- Conduct exposure/risk assessment using appropriate methodology.

FIGURE 1.2. Components of a pesticide field runoff study for evaluating exposure/risk assessment using mathematical models

1.3 FORMAT OF MANUAL

This user manual is divided into six sections, inclusive of this introduction. Section II contains an overview of the overall design and performance procedures. Section III describes specific design considerations including: site selection, required site description information, data requirements, sampling network design, sampling equipment and instrumentation, and sampling procedures. Section IV provides essential elements for quality assurance planning. Section V contains information on the development of a data base management system including record keeping, data entry, storing data on computer, data manipulation, archiving, and data base documentation. Section VI provides information on model calibration and testing. This is followed by several appendices. Appendix A provides conversion factors for environmental data bases. Appendix B consists of random unit tables. Appendix C provides percentage points of the student's t-distribution. Appendix D is a list of soil series names and hydrologic classifications. Appendix E contains the design specifications for a surface soil sampler.

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SECTION 2

OVERVIEW OF DESIGN AND PERFORMANCE PROCEDURES

This section provides an overview of the procedures involved in designing a field program for pesticide runoff data collection. It is comprised of four major subsections:

- design concept
- formulation of study goals
- overview of design specification by topical areas
- cause and effect relationships in the pesticide runoff process

The design concept should be an overriding theme throughout the design and implementation of the field study. It encompasses two subordinate concepts: the formulation of exact study goals and the specification of design alternatives, which should always be evaluated and implemented in light of the goals. The last section is included to briefly highlight some of the cause and effect relationships in the pesticide runoff process. An understanding of these relationships is helpful in evaluating the impact of alternative designs on the goals of the program.

2.1 CONCEPT OF DESIGN

Design is a concept with which almost everyone is familiar but of which few have a full appreciation. The American Heritage Dictionary of the English Language defines design as "the invention and disposition of the forms, parts or details of something according to a plan." The key words in this definition are "details" and "plan." In order to specify the details, the plan must be carefully formulated; and in order to develop a plan, the program goals must be clearly defined.

The design, then, consists of two distinct phases. The first is a concise and well defined statement of the program goals or objectives. The soundness of the design will depend heavily upon how well the objectives are defined. The objectives should be as specific as possible. When properly defined, they form a set of design criteria that can be used to evaluate the appropriateness of the various alternatives used to achieve them. If, at any time during the design process, the question "Why are we doing this?" cannot be answered, then the project objectives have been incompletely specified.

Once the project goals or objectives are known, one can formulate a list of pathways or alternatives to follow in order to achieve the goals. The selected alternatives will be the "details" of the design. The alternatives should always be compared and selected based upon their anticipated impact on the design objectives. This implies that a cause and effect relationship between an alternative and the resulting outcome is understood. If such a relationship is unknown, it may be necessary to experiment to determine it. Obviously, the designer benefits greatly by being familiar with literature on the subject and ongoing research. If, at any time, the question "Why are we doing this this way?" cannot be answered, then proper cause and effect has not been established between design alternatives and program goals. Figure 2.1 shows a general framework for the design process.

2.2 FORMULATION OF STUDY GOALS

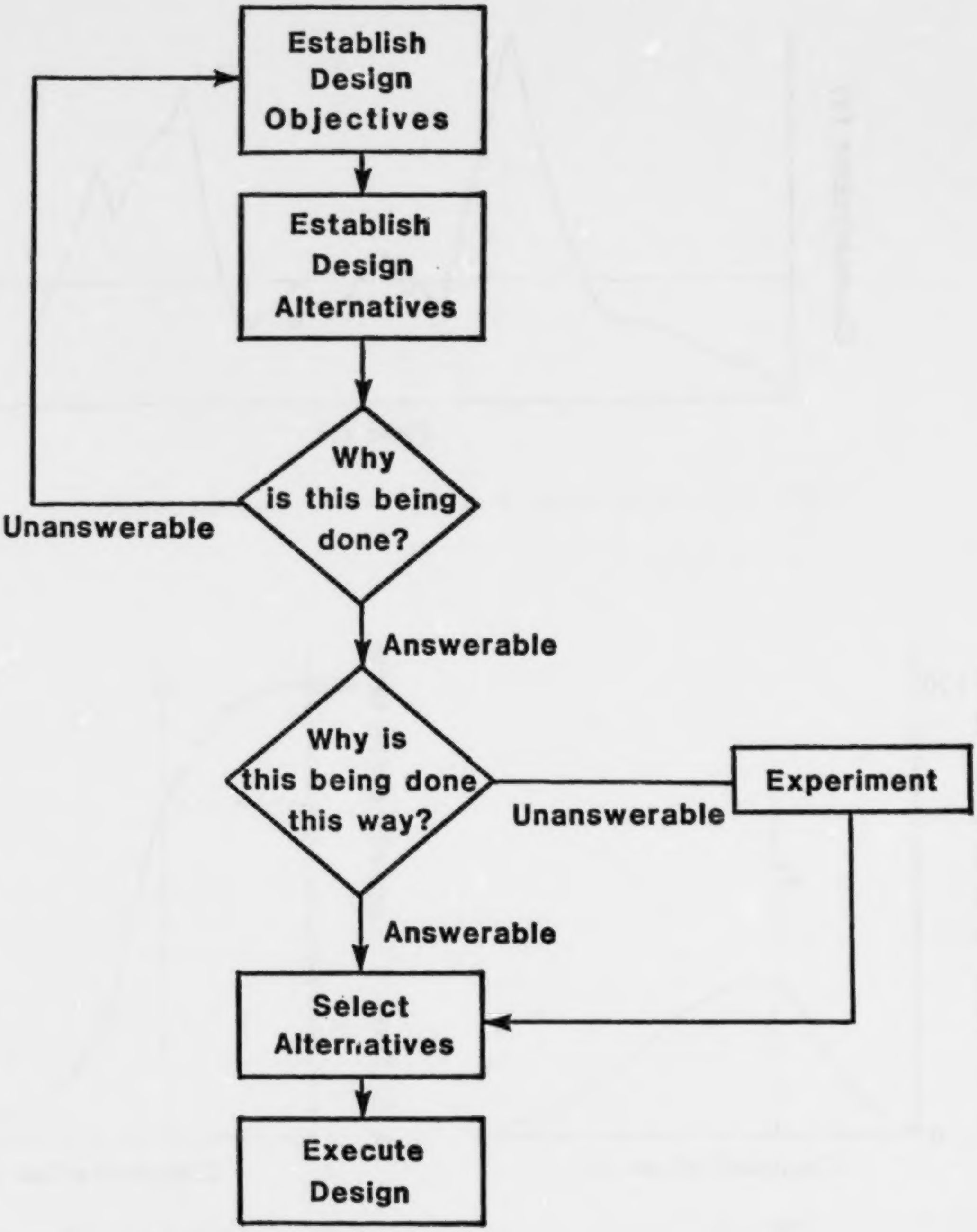
For our purposes, the overall objective for conducting a field program, as discussed in Section 1, has been specified. To reiterate, we are primarily interested in collecting data through field studies that can be used to perform exposure assessments with computer simulation models.

Questions that come to mind after establishing this objective are:

- What constitutes an exposure assessment?
- What models can be used?
- What data will be required?

2.2.1 Exposure Assessment Defined

An exposure assessment is a determination of the magnitude (concentration) of a toxicant to which an organism will be exposed over a given period of time (duration). The model produces a time series of toxicant concentrations in a specific medium (e.g., water, air, soil) such as appears in Figure 2.2. The time series can be compared to a critical value of the concentration y (this might be, for instance, the LC50 value, i.e., concentration for 50% mortality). This type of analysis easily shows whether the criterion is exceeded and gives a qualitative feel for the severity of the exceedence state. If we determine how often it is at a particular level or within a specified range, we can create a frequency distribution of the values of "y" (Figure 2.3). If, in addition, we choose any value of y in Figure 2.2 and determine the area under the curve to the right of that value we can plot Figure 2.4, which is a cumulative frequency distribution of the toxicant concentration. In other words, it shows the chance that any given value "y" that we select will be exceeded. If our example time series is long enough, then the "chance" approaches the true "probability" that "y" will be exceeded.



Establish Design Objectives
Establish Design Alternatives
Why is this being done?
Unanswerable
Answerable
Why is this being done this way?
Unanswerable
Experiment
Answerable
Select Alternatives
Execute Design

FIGURE 2.1. Schematic of the design process.

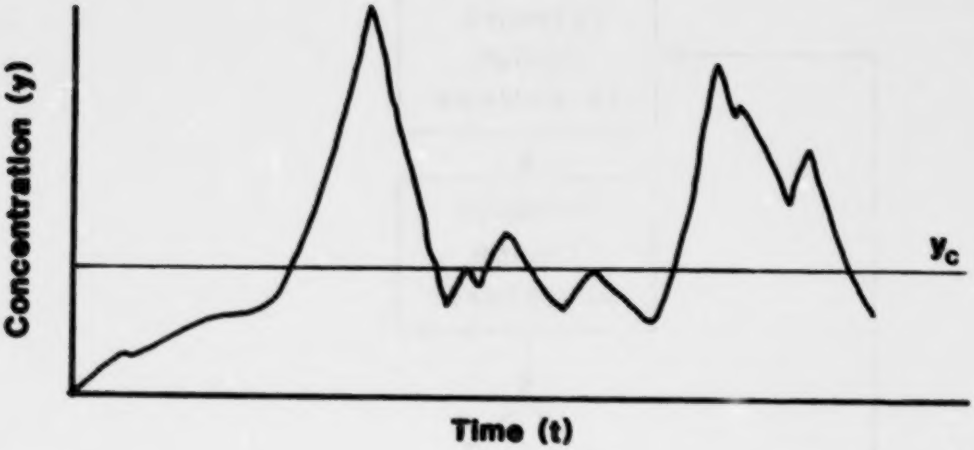


FIGURE 2.2. Time series plot of toxicant concentration.

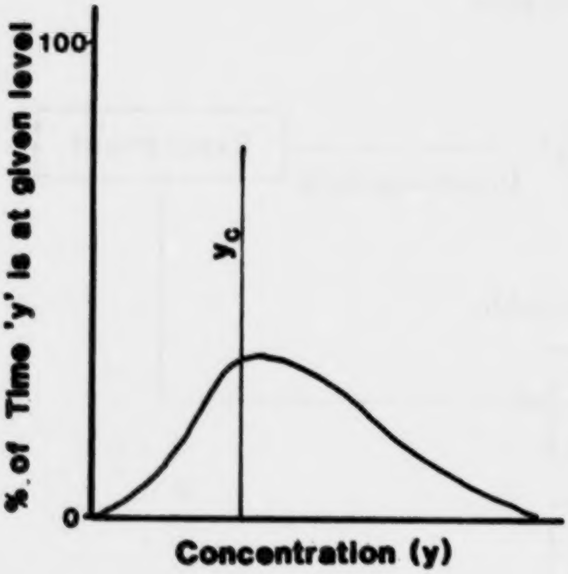


FIGURE 2.3. Frequency distribution of toxicant concentrations.

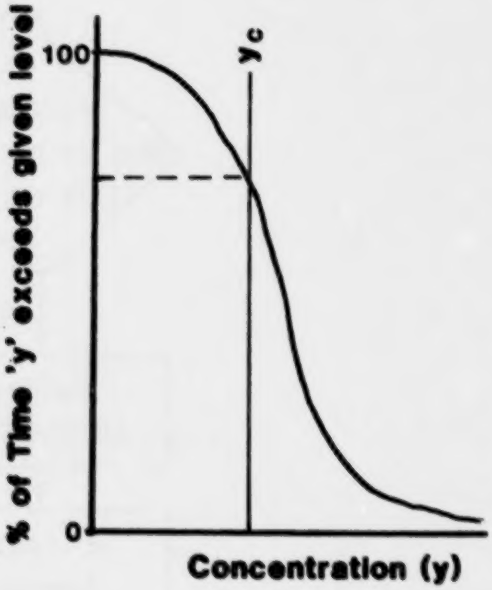


FIGURE 2.4. Cumulative frequency distribution of toxicant concentrations.

Thus far, only the concentration to which the organism will be exposed has been discussed and nothing has been said concerning the duration of the event. If we take the same time series and impose a window of length t on it at level y_c (Figure 2.5), and move it incrementally forward in time, we can make a statement concerning the toxicant concentration within the duration window. Normally, the average concentration within the window is used. The resulting cumulative frequency distribution shows the chance that the moving average of duration t_c will exceed the critical value of "y", y_c. The moving average window should be the same length as that specified for y_c. For instance, if the 48-hour LC50 is the criterion, a 48-hour moving window should be used to average the data in the simulated time series. The use of the moving window for averaging the time series allows us to compare both the concentration and duration against the standard.

The chance or probability that the moving average concentration exceeds the survival standard of a given species is the essence of the exposure assessment. This type of information provides an estimate of the risk taken in using this chemical under the conditions of the model simulation.

In this manual we are discussing the design of programs to produce pesticide runoff data. How, then, does this fit within the general framework of an exposure assessment? Figure 2.6 demonstrates the relationship. The pesticide is introduced to the watershed system at the top of the figure. Precipitation events produce runoff and sediment transport events, which, at the field scale, are intermittent. That is, runoff and transport only occur during or immediately following rainfall (or snowmelt) events. The pesticide either dissolves in water or attaches to sediments and moves off the field into adjacent streams. In these streams, the dissolved pesticide may be diluted by uncontaminated water and pesticide attached to sediments may deposit to the stream bed. In general, because of these mixing processes,

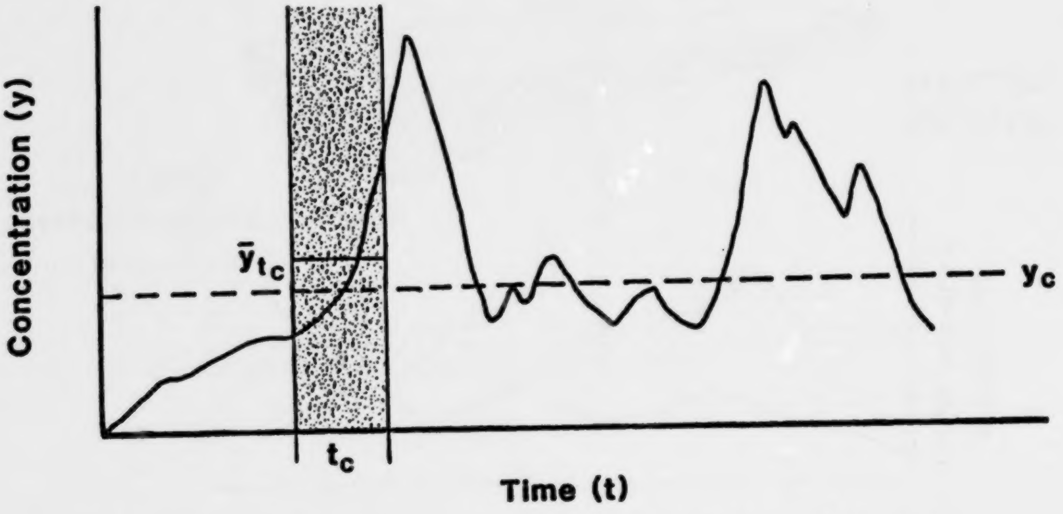


FIGURE 2.5. Time series of toxicant concentrations with moving average window of duration t_c.

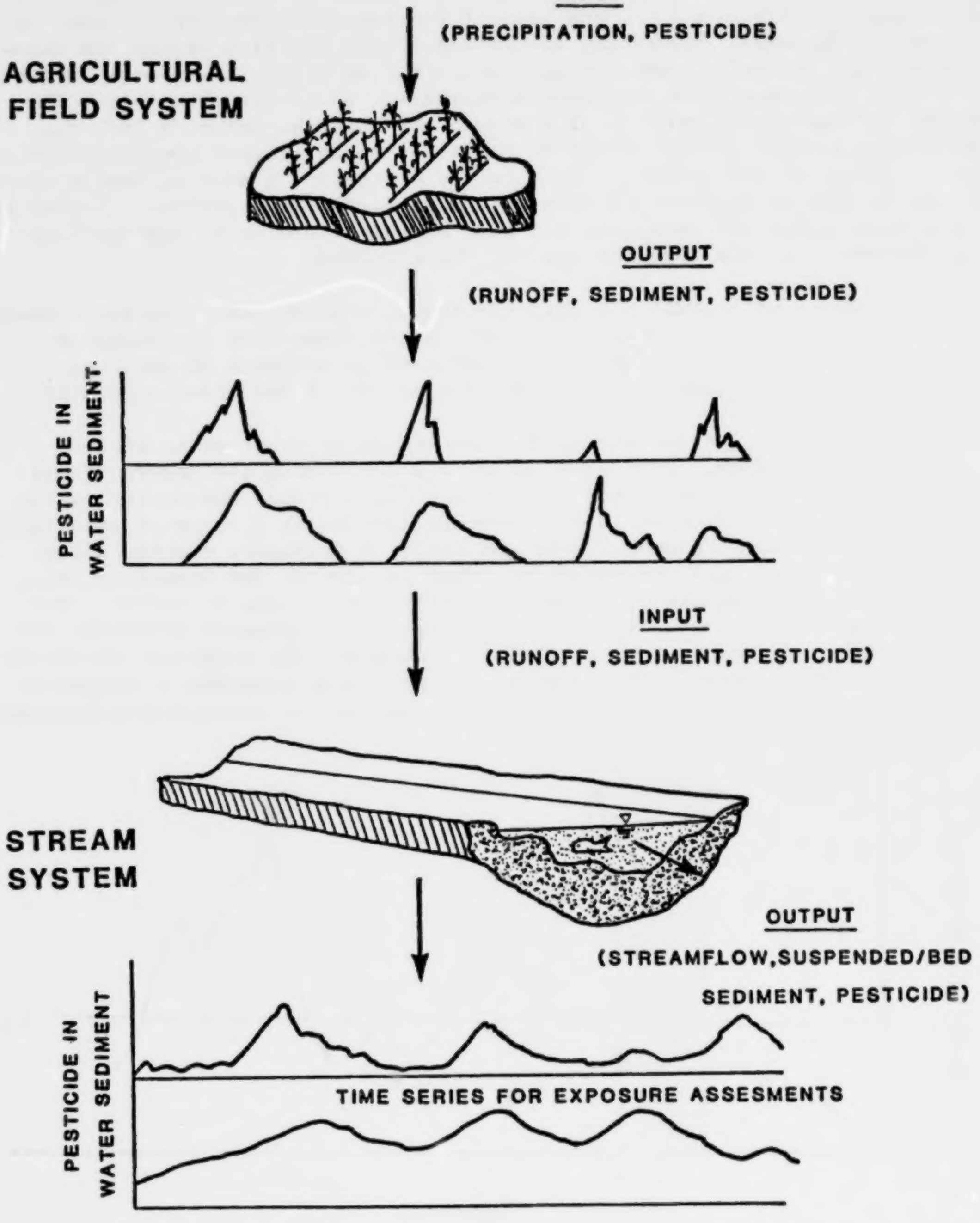

INPUT
(PRECIPITATION, PESTICIDE)
AGRICULTURAL FIELD SYSTEM
OUTPUT
(RUNOFF, SEDIMENT, PESTICIDE)
PESTICIDE IN WATER SEDIMENT
INPUT
(RUNOFF, SEDIMENT, PESTICIDE)
STREAM SYSTEM
OUTPUT
(STREAMFLOW,SUSPENDED/BED SEDIMENT, PESTICIDE)
PESTICIDE IN WATER SEDIMENT
TIME SERIES FOR EXPOSURE ASSESMENTS

FIGURE 2.6. Schematic of natural systems that produce environmental time series of pesticide concentrations.

a larger stream system produces a more continuous time series of concentrations, especially if the pesticide is not subject to rapid degradation. It is these concentrations in the stream to which aquatic species or humans may be exposed, and therefore are used in the exposure assessment. Thus, pesticide runoff data developed from field scale programs must be linked with instream (or impoundment) conditions in order to perform a complete exposure assessment.

2.2.2 Motivation for Use of Models

The issue of which models to use brings up the larger question of why we are using models to perform this assessment. Perhaps the greatest motivation is the prohibitive cost of performing field studies for extended periods of time. Using models combined with limited field studies allows us to "extend" the pesticide runoff record through simulation, thus obtaining an equivalent period of data at substantially reduced costs. The purpose of this extension is to obtain from the sample data a better estimate of the true probability of exceeding the critical value. Another factor is the long time required to perform field studies. Here again, once models are calibrated and validated to the watershed of interest, the extension of the record through simulation is more a matter of minutes or hours than of years. These aspects of using models become attractive, for instance, to the company attempting to put products on the market in a timely manner or to the regulator charged with making timely decisions on chemical usage that may affect human health.

The foregoing arguments are based on the premise that models are available that can accurately represent the runoff losses from a given watershed for a wide variety of pesticides, watershed, meteorologic and management conditions. The previous decade has witnessed the birth and "coming-of-age" of several simulation models for this purpose.

2.2.3 Currently Available Models

Two pesticide runoff models that are currently widely used in the scientific/engineering community are HSPF (which includes ARM-Agricultural Runoff Management Model), developed for the U.S. Environmental Protection Agency (Johanson et al., 1984; Donigian et al., 1984) and CREAMS, which was developed by the U.S. Department of Agriculture (USDA, 1980). While these models are somewhat different in their approaches, they both require certain basic information common to their usage. The data required of the field study will be those data necessary to use these models, or models like them, to extend the record of field study observations.

2.2.4 Model Data Requirements

The necessary data break down into three broad but distinct groups:

- input time series for driving the model

- output time series for comparison to model simulations
- data required to establish model parameters

It is normal that the input time series include precipitation and some form of energy input. Precipitation inputs range in time increments of daily down to 5 minutes. For energy inputs, either pan evaporation, temperature and/or total incident solar radiation are normally required, usually on a daily time step.

Output time series can include any number and type of observations that can be made on the watershed. Examples are soil moisture, pesticide soil concentrations, and runoff of water, sediment and pesticide.

The remaining category of data is that required for model parameter evaluation. This is usually where most of the differences in data requirements between various models occur. The parameters break down into two basic types, physically based and empirical. The physically based parameters (e.g., pesticide-soil adsorption coefficient, soil bulk density) are normally measured either in the field or laboratory, or have been compiled by previous researchers. Empirical constants have either been tabulated as a result of previous observations or model simulations, and/or must be evaluated as part of the model calibration exercise. Improvement in simulation of output time series can usually be accomplished by adjustment of one or more of the empirical parameters required by the model after the first estimate of the parameter(s) has been made.

2.3 DESIGN SPECIFICATIONS

The specifications of design alternatives are the chief subject of the remainder of this text. These specifications are divided into a number of subject areas, namely:

- Site selection
- Data requirements
- Sampling network design
- Sampling equipment and watershed instrumentation
- Data base management
- Data analysis and modeling

Site selection is a critical issue because it defines the climatic regime and soils/watershed characteristics. These affect virtually all aspects of pesticide transport. Included in this choice are issues concerning selection of soil and water conservation management practices and pesticide use and application procedures. The impacts of climate, watershed and soils characteristics and management practices are discussed in Section 2.4. Data required as products of the field study can vary depending upon the computer model(s) selected to perform the exposure assessment. Thus, the model or models to be used should be selected prior to initiation of the study.

Once the type of data to be collected is known, issues of the sampling design can be addressed.

The sampling network design must specify the measurements of certain variables or parameters at defined points in space and time. The frequency of sampling will depend on the dynamics of the process being sampled. The length of the sampling period will, in general, depend upon the persistence of the chemical, although some time series measurements may be required year round if a multiple year study is being done and continuous simulation models are used. Degree of sampling in space depends upon the degree of spatial heterogeneity that occurs in time series (e.g., precipitation) or parameters (e.g., crop canopy).

Once the sampling network has been designed, procedures for taking samples should be specified. These procedures will require that certain equipment be available to collect, store, and transport samples. This equipment may be portable or may require permanent or semi-permanent installation on the watershed.

Design of the data base and data base management system should also be considered before the initiation of the data collection activity. Included in this are issues such as:

- What data should be put into the computer?
- How should it be stored, checked, and verified?
- How should missing data be estimated, if necessary?

Decisions concerning these issues may affect the design of the sampling program and the selection of equipment used to make measurements.

The type of data analysis to be performed should also be considered. In some instances this can affect the sampling network design (for instance, in the case of classical factorial or least squares experiments). For our purposes, data analysis is considered to be the reduction of raw data for model parameter estimation or for comparison of simulated model outputs to observed data.

2.4 CAUSE AND EFFECT RELATIONSHIPS IN THE PESTICIDE RUNOFF PROCESS

To better select design alternatives for successfully conducting a field program to measure pesticide runoff, a discussion of relationships among the factors that control the process is in order.

Pesticide lost in runoff is the sum of that lost in the dissolved phase (in water) and in the adsorbed phase (on sediment). A knowledge of the runoff and erosion processes is essential to understanding the more complex issue of pesticide runoff. These will be discussed first, followed by a discussion of the impact of edaphic and conservation practices on soil and water losses. Finally, the impact of management practices on chemical losses will be addressed.

2.4.1 The Runoff and Sediment Erosion Processes

For these purposes, runoff will be defined as water that moves over the land surface at some point from the time that it impinges upon the land surface until it exits the field edge. There are two ways in which runoff can occur (Freeze, 1981). The first, known as Hortonian flow, occurs when the precipitation rate exceeds the hydraulic conductivity (capability to transmit water) of the surface soil (Horton, 1933). Rainfall contacting the soil surface begins to infiltrate downward in the soil profile as moisture content increases close to the surface. At some point, ponding occurs (i.e., the soil surface becomes saturated). At this point the rainfall rate exceeds the infiltration rate and surface runoff (overland flow) occurs. The second, known as Dunne-type flow is caused by the rising of a shallow water table, which saturates the surface soil, thereby causing overland flow to occur (Dunne, 1978). Hortonian flow is more common on upland areas, whereas Dunne-type flow occurs on flatter slopes usually near channels or in poorly drained areas.

As water moves over the surface of the land, it exerts a shearing force on the soil surface. If the shearing force exceeds a critical value for a particular soil particle (which is a function primarily of soil particle size and soil structure) then that particle will be entrained by the flow and move downslope. As long as the velocities in the flowing water remain high, the particles will remain suspended. If velocities are decreased, however, then larger, more dense particles will begin to settle out and be redeposited to the soil surface. At this point they may roll along the soil surface, or, as velocities drop further, they will stop moving altogether.

Naturally, the smaller and less dense the particle, the easier it is for runoff water to entrain it. High intensity rainfalls tend to pulverize soil aggregates into smaller particles which enhances the supply of fine sediments available to be transported by runoff. On the other hand, decreasing soil moisture content tends to cause reaggregation or crusting of the soil, near the surface. This tends to cause a decrease in the supply of fine sediments. Quite naturally, tillage events that drastically alter soil structure also increase fine sediment supply.

Runoff moving over the soil surface will inevitably transport some particles as long as the supply of particles lasts; however, the capability to transport particles is limited. Thus, two cases can arise which limit the quantity of particles transported: the availability of particles (i.e., supply limitation) or the capability of the flow to transport particles (i.e., transport limitation).

Based on the understanding of these processes, factors can be identified that are important in describing the processes of runoff and sediment transport. These break down into four groups:

- climatic
- topographic
- soils
- management

The chief climatic factor is the intensity of rainfall. Intensities must be great enough to exceed soil infiltration rates or to cause surface saturation by rapidly rising water tables to produce runoff. High intensity rainfalls, as noted previously, detach soil particles from aggregates, thereby producing a larger supply of the fine sediments that are more easily transported. Once runoff occurs, topographic features such as long, steep slopes will tend to produce higher runoff velocities, increasing the capability of flow to detach and transport sediment. In addition, some soils are naturally more erodible than others. Generally, soils with a higher fraction of silt size particles and organic matter tend to erode more easily than those having higher percentages of sand and clay size particles.

Management practices can affect characteristics of the watershed which may have drastic impacts on runoff and sediment transport. Nonstructural management practices are those that require no physical alteration of the watershed itself. These include tillage practices, crop rotations and improvement of soil fertility. Structural management practices include terracing, grading and construction of grassed waterways, tile drains, etc. A good review of the literature concerning the effects of management practices for both control of runoff and erosion can be found in Woolhiser (1976) and Wischmeier (1976). As a quick reference, a qualitative summary of the effects of certain management practices on runoff and sediment transport is shown in Table 2.1 (Donigian et al., 1983). The designer should be aware, at least qualitatively, of the impact of management options upon quantities of runoff and sediment moving from the field areas.

2.4.2 Interactions and Fate of Pesticides in Soils

Superimposed upon the dynamics of the runoff and sediment transport processes are the dynamics of pesticide behavior in soils. Although affected by these transport processes, the quantity of pesticide that will appear in runoff is primarily a function of the quantity of pesticide present in surface soil and its partitioning between the dissolved and sorbed phases. The partitioning behavior, usually expressed as the ratio of chemical concentration in he solid phase versus the liquid phase (K_p) has a direct influence on chemical runoff behavior. Very weakly sorbed compounds move primarily in *the solution phase and are almost independent of sediment transport. Strongly* sorbed materials are, however, transported mainly in the sediment phase and the transport of sediments and chemical are closely related. Many processes

TABLE 2.1. RELATIVE IMPACT OF SELECTED MANAGEMENT PRACTICES ON AGRICULTURAL RUNOFF PROCESSES/COMPONENTS COMPARED TO CONVENTIONAL PRACTICES[1]

	Runoff-Related		Sediment-Related				
	Overland Flow	Subsurface Flow	Detachment by Rainfall	Detachment/Scour by Overland Flow	Transport by Overland Flow	Availability/Production of Sediment Fines	Aggregation/ Compaction
MANAGEMENT PRACTICE							
Nonstructural Measures							
1. No Tillage	-	+	-	-	-	-	-
2. Conservation Tillage	-	+	-	-	-	-	-
3. Contour Farming	-	0,+	0	-	-	0	0
4. Graded Rows	-,+?	+,-?	0	-	-?	0	0
5. Contour Strip Cropping[2]	-	0,+	-,0	-	-	-,0	0
6. Spring Plowing[3]	-	+	-	-	-	-,0	0?
7. Sod-Based Rotation[4]	-	+?	-	-	-	-	?
8. Winter Crop Cover	-	+	-	-	-	+,0	-,0
9. Permanent Meadow	-	+?	-	-	-	-	-,+
10. Mechanical Cultivation	-	+	+	+	+	+	-
11. Crop Rotation	-	+	0	0	0	0	0
STRUCTURAL MEASURES							
1. Terraces	-	0,+	0	-	0,-	0	0
2. Diversions	+	-?	0	-	+?	0	0
3. Grassed Waterways[5]	-	0	-	-	-	0	0
4. Filter Strips[6]	-?	0	-	-	-	0	0
5. Tile Drainage	-	+	0	-,0	-,0	0	0
6. Retention Basins	0	0	0	0	0	0	0
INPUT MANAGEMENT OPTIONS							
1. Improve Soil Fertility	-	?	-	-,0	-,0	0	-
2. Eliminate Excessive Applications	0	0	0	0	0	0	0
3. Optimize Timing of Planting and Chemical Applications	0	0	0	0	0	0	0
4. Control Release and Transformation Rates	0	0	0	0	0	0	0
5. Biological Control	-	?	+	+	+	?	?
6. Incorporation of Applied Chemicals by Tillage	-	?	+	+	+	+	-

---

[1] Many practices have effects which are time-dependent because they are applied in different seasons of the year. Comparisons indicate long term deviations from base conditions.

[2] Processes are considered only within the strips of grass or close-growing crops growing between the cultivated crops.

[3] The overall effects of shifting plowing from fall to spring are considered.

[4] Processes are considered for the sod year only.

[5] Processes are considered only within the grassed waterway.

[6] Processes are considered only within the filter strip.

Source: Donigian et al., 1983

affect the quantity of pesticide on the watershed and its partitioning. The major processes can be organized into source, sink and intrasystem transfer categories.

Sources include spills and application events. Chemical sinks are photolysis (direct, sensitized); hydrolysis (acid, neutral, base catalyzed); biodegradation; volatilization; plant metabolism; runoff, erosion and leaching losses; and removal in harvested material. Intrasystem transfers occur through foliar washoff, organism uptake (bioaccumulation), foliar absorption, adsorption, acid/base equilibrium, and plant uptake.

Sources, for our purposes, are limited to application events although spills may also be of concern. Sinks include photolysis, which may occur at plant or soil surfaces, and hydrolysis, which may be catalyzed by acidic or basic conditions, depending upon the compound. Organisms may play a large part in the breakdown of the chemical, and volatilization acts to remove the chemical from soil and plant surfaces. Chemical reactions can convert the chemical between various forms and radically alter its environmental properties. Runoff, leaching, and erosion losses are the major processes by which substances are transported from the land or land surface into water supplies.

Several processes also serve to cycle or move chemicals out of the soil phase where they may be made temporarily unavailable for transport out of the system. Plants can play a major role by adsorbing chemicals through the foliage or roots and translocating it to other plant parts. This temporarily bound residue may become available once again through leaching and decay of dead plant material. Organisms can also temporarily immobilize portions of the chemical. Speciation reactions can shift the chemical between the solid or dissolved phases making the chemical less or more available to leach through the soil profile.

In-depth discussions of the fate and transport of pesticides in soils can be found in Pionke and Chesters (1973), Leonard et al. (1976), and Donigian and Dean (1984). The field program designer should have prior knowledge of approximate degradation rates and adsorption characteristics of the pesticide as these will substantially affect the sampling program design.

In addition to watershed management practices that modify the production of runoff and erosion from agricultural watersheds, an additional set of options for pesticide management also come into play. These options are:

- Application Mode
    - Granular
        - incorporated
        - unincorporated

- Liquid
    - incorporated
    - unincorporated

- Application Types
    - Aerial
    - Airblast
    - Ground rig
    - Chemigation

- Application Timing
    - Season
    - Time of day

- Formulation
    - Emulsifiable concentrate
    - Wettable powder
    - Granules
    - Solutions
    - Flowable powders
    - Micro encapsulated forms

- Application Rate

Application mode will obviously affect the amount of the chemical applied directly to the soil and thus directly available for runoff. For instance, spraying the soil surface directly, as with a preemergence herbicide, would tend to make pesticide more directly available for runoff. Soil incorporation, on the other hand, may place much of the compound below the surface soil zone from which runoff is normally produced. Application timing with regard to season and also to individual storm events is extremely important, especially for short-lived chemicals. Pesticides degrade in the environment. Therefore, the shorter the time between pesticide application and a hydrologic event producing runoff, the higher the probability that the pesticide will appear in runoff. Runoff potential is enhanced if pesticides are applied during times of the year when the probability of runoff-producing events is high. This is particularly true since antecedent moisture contents also tend to be higher during periods of high rainfall activity. Naturally, application rate and formulation have significant impacts on pesticide availability. Caro (1976) has provided a discussion of the impacts of various practices upon the runoff of pesticides in agricultural applications.

2.4.3 Impact of Runoff, Sediment Transport and Pesticide Fate Processes on Study Design

The principle concept concerning the collection of pesticide runoff data is that the events tend to occur infrequently and in a very short time frame when they do occur. In a pesticide runoff study in Iowa, for instance (Baker et al., 1979), only two runoff events of any consequence occurred between application and nearly complete degradation of the pesticide over a 2-year period. On the other hand, in a pesticide runoff study performed in Watkinsville, Georgia, 28 runoff events occurred during the 1972 growing season (Smith et al., 1978). Ten of these events yielded measurable concentrations of paraquat (a compound with slow degradation that was applied above normal rates), however, while only seven yielded measurable concentrations of trifluralin (a compound with higher degradation rates than paraquat). The duration of some of the events from 1973 in the same study was approximately 1.5 hours. Because of the exponential dependence of sediment transport processes on flow, the bulk of the chemical may be transported in still shorter time frames, when flows are at or near peak values.

For these reasons, pesticide runoff sampling tends to be more difficult to perform than, for instance, leaching or instream sampling where the dynamics of the events tend to be smoothed out. The designer of such studies should be aware that in many cases the dynamics of a particular sequence of events may require that the study be shortened or lengthened considerably or that sampling schedules may change subject to the "whims of nature." In general, the designer should attempt to build flexibility and the capability to react quickly into the field program.

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SECTION 3

SPECIFIC DESIGN CONSIDERATION

The objective of this section is to provide specific design criteria for evaluating pesticide runoff including site selection, required site description information, data requirements, sampling network design, sampling equipment and instrumentation, sampling procedures, transporting samples, field record keeping, analytical methodology, and runoff and soil data computation.

3.1 SITE SELECTION

The careful selection of the sites(s) on which pesticide runoff studies are conducted will contribute greatly to the success of the field program and will have a direct impact on the value of the data obtained. If an exposure assessment is the ultimate objective of the field study/modeling program, the site to be chosen should be representative of the general area in which the chemical is likely to be used. "Representativeness" requires that the properties of the watershed that have major impact on the pesticide runoff process not be significantly different from the area being represented. Unfortunately, a significance level is difficult to determine, either in the aggregate or for individual characteristics, and is left up to the judgment of the designer.

A flow chart for the selection of watersheds is shown in Figure 3.1.

3.1.1 Delineation of Unique Areas

The pesticide(s) and crop(s) of interest are usually known. Major crop growing areas can be easily identified. Areas of major corn, grain sorghum, wheat, cotton, soybeans, orchard and vegetable production are shown in Figures 3.2 through 3.8.

Next, these areas should be subdivided according to the major factors that affect pesticide runoff. These factors include:

- Climate
  - Rainfall Depth
  - Rainfall Intensity
  - Evapotranspiration

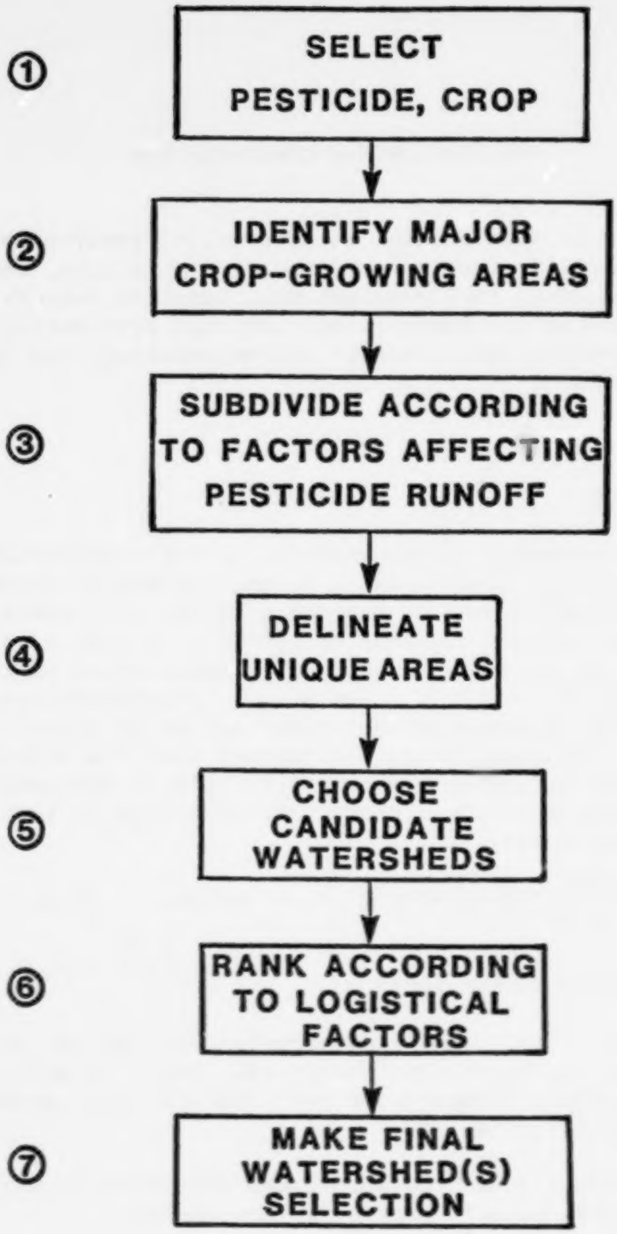

①
SELECT PESTICIDE, CROP
②
IDENTIFY MAJOR CROP-GROWING AREAS
③
SUBDIVIDE ACCORDING TO FACTORS AFFECTING PESTICIDE RUNOFF
④
DELINEATE UNIQUE AREAS
⑤
CHOOSE CANDIDATE WATERSHEDS
⑥
RANK ACCORDING TO LOGISTICAL FACTORS
⑦
MAKE FINAL WATERSHED(S) SELECTION

FIGURE 3.1. Flow chart for selection of watershed for field studies to support modeling exposure assessments.

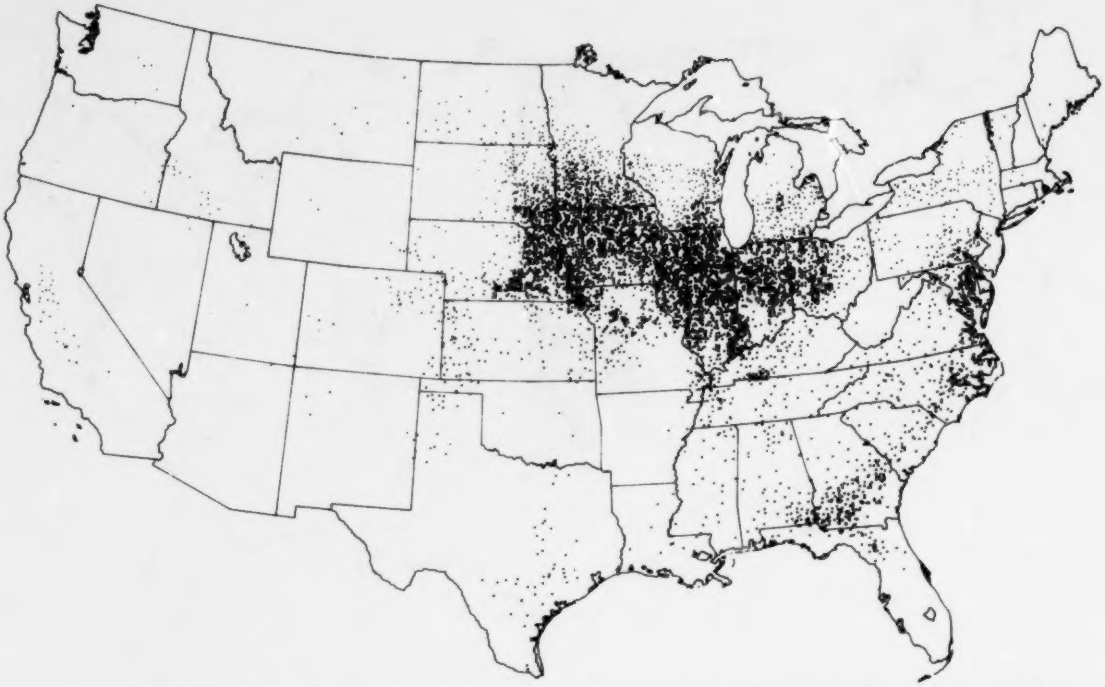


FIGURE 3.2. Corn harvested for all purposes (U.S. Department of Commerce, 1982).

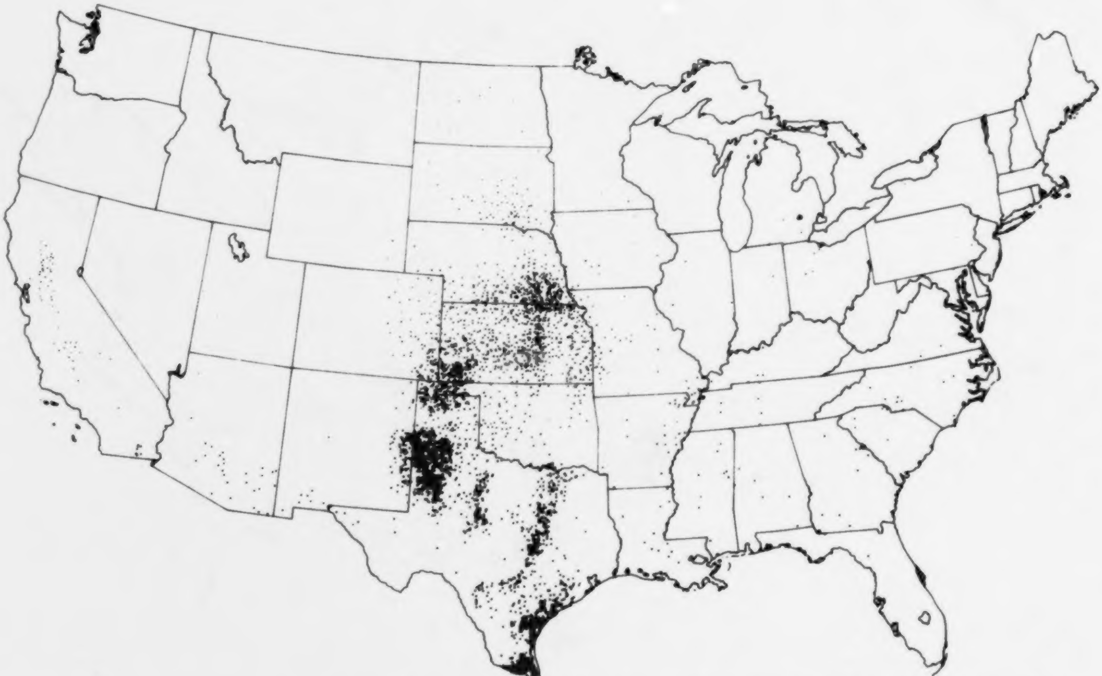


FIGURE 3.3. Sorghums harvested for all purposes except syrup (U.S. Department of Commerce, 1982).

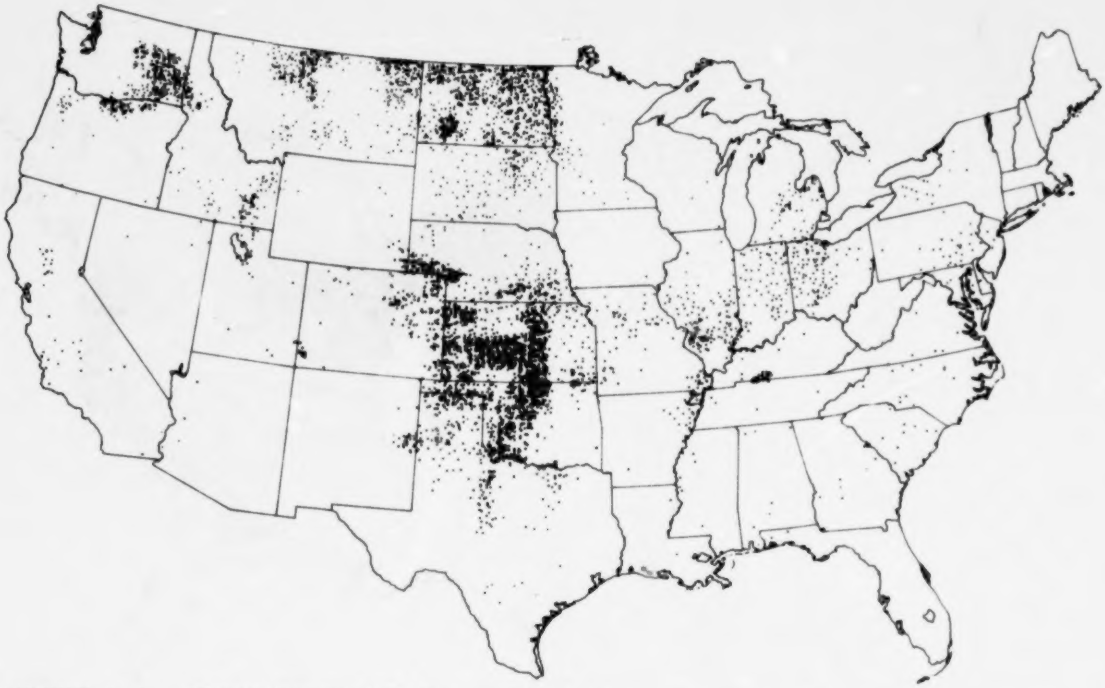


FIGURE 3.4. Wheat harvested for grain (U.S. Department of Commerce, 1982).

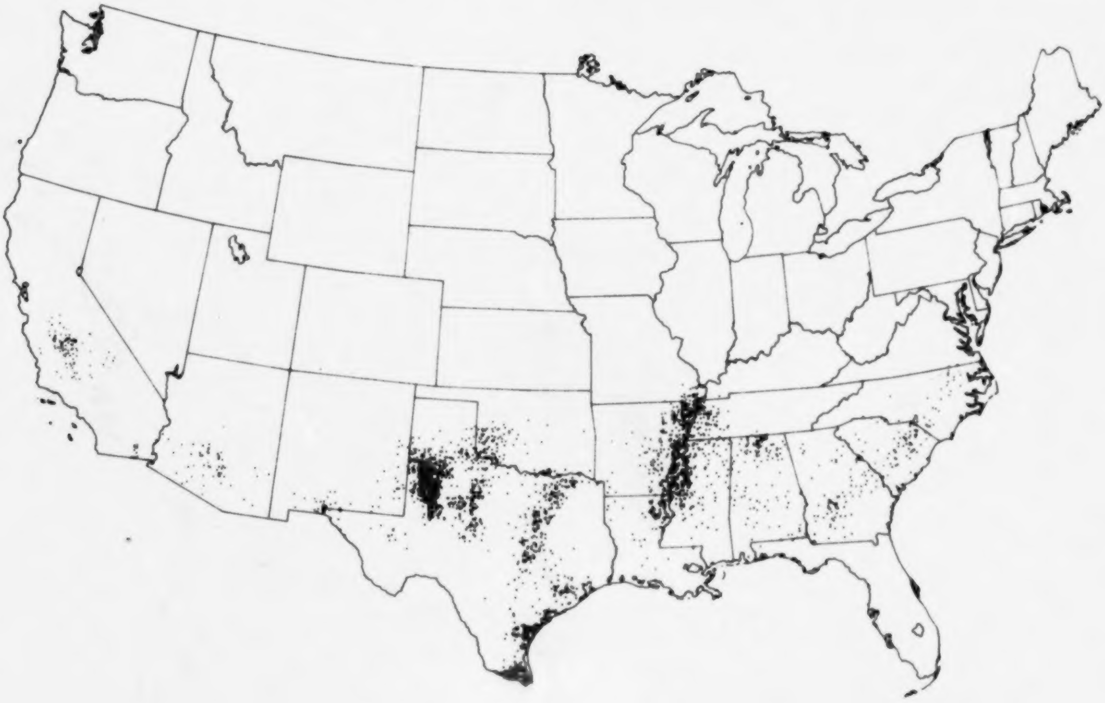


FIGURE 3.5. Cotton harvested (U.S. Department of Commerce, 1982).

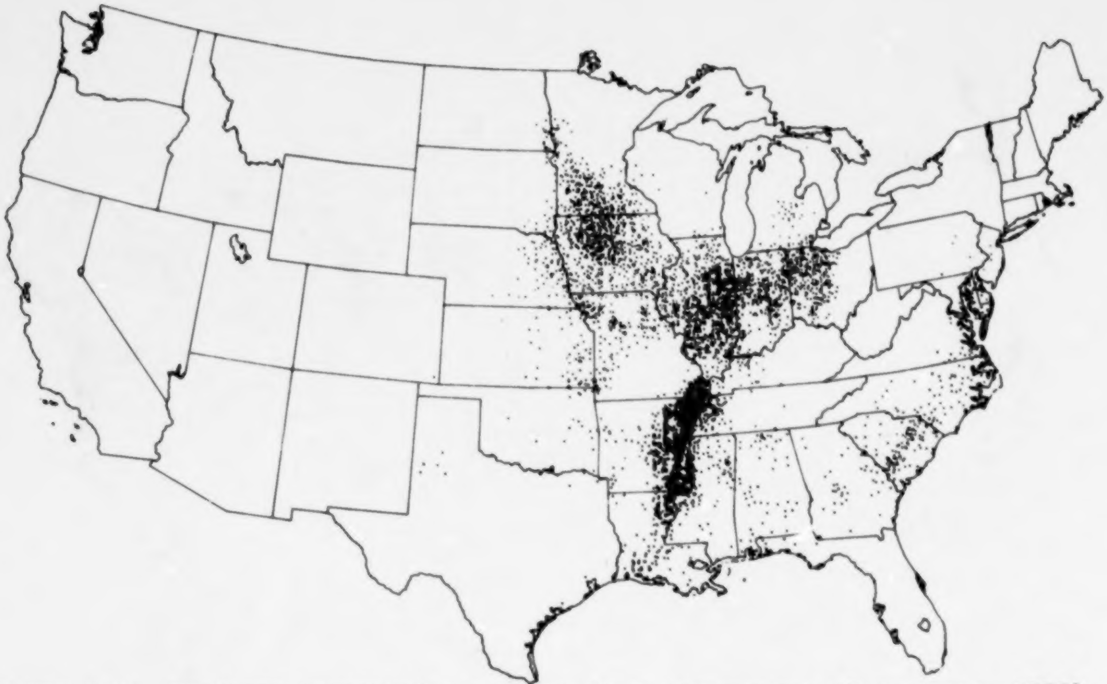


FIGURE 3.6. Soybeans harvested for beans (U.S. Department of Commerce, 1982).

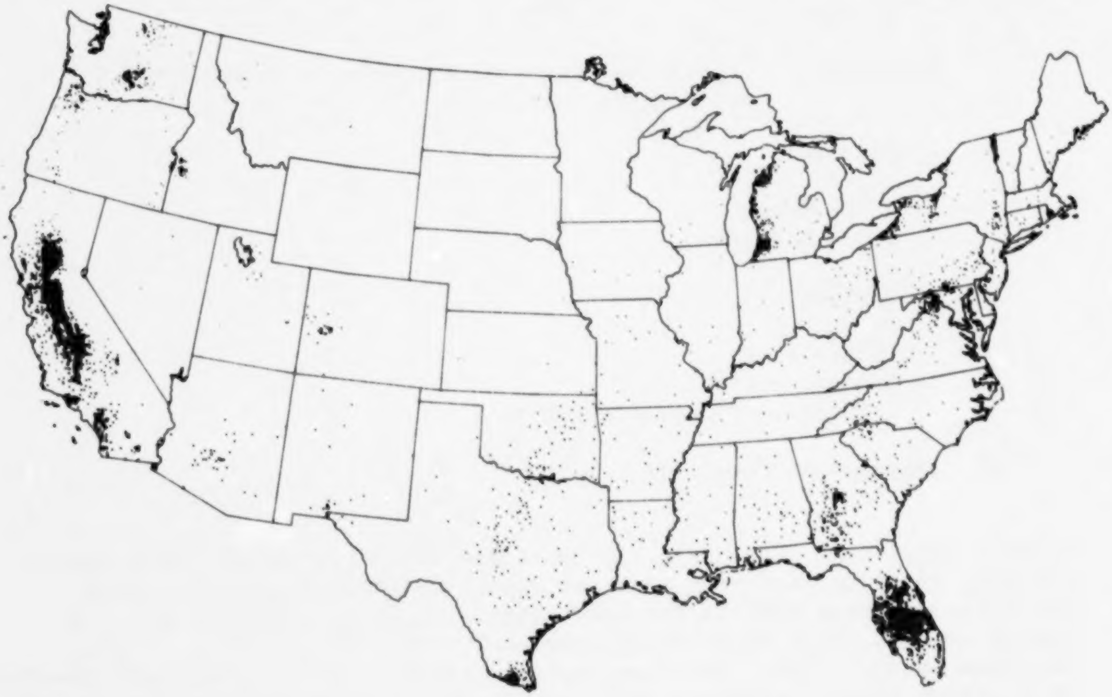


FIGURE 3.7. Land in orchards (U.S. Department of Commerce, 1982).

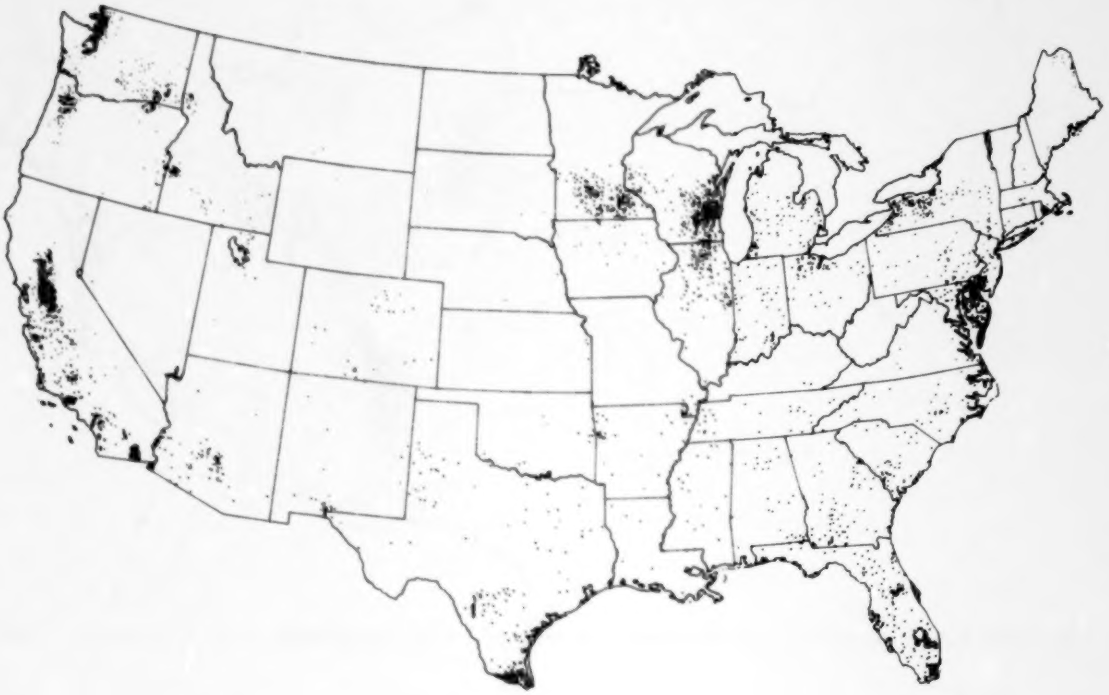


FIGURE 3.8. Vegetables harvested for sale (U.S. Department of Commerce, 1982).

- Topography
  - Slope Length
  - Slope Steepness
- Soil Type
  - Erodibility
  - Organic Matter
  - Infiltration Characteristics
- Management Practices

Climatically, both total rainfall depth and intensity affect total runoff and peak runoff rates--both of which affect sediment transport. Crop evapotranspiration affects the antecedent soil water condition prior to runoff events. Antecedent soil water has a definite impact on runoff, Langdale et al., 1983. Two topographical factors, slope length and steepness, will affect runoff velocities and, hence, the capability of flow to detach and transport sediment. The soil type is also of primary concern. Erodibility determines the sediment yield per unit shear stress on the soil; the organic matter content affects erodibility and the degree of pesticide adsorption. Infiltration characteristics affect the timing and quantity of runoff water. The impacts of management on runoff and sediment transport have been overviewed in Section 2.4.

Fortunately, the effects of most of the above factors on runoff have been integrated in a study done by the U.S. Dept. of Agriculture in cooperation with the U.S. Environmental Protection Agency (USDA, 1975). The Department of Agriculture has divided the 48 contiguous states into 156 land resource areas (LRAs). An LRA is defined as "a geographic area characterized by a particular pattern of soil type, topography, climate, water resources, land use and type of farming." Although differences exist among these factors within a land resource area, a "representative" meteorologic station, predominant soil type and runoff curves numbers were assigned to each. Ten to twenty-five years of meteorologic records were then used to simulate runoff for each LRA using a simulation model. The results are shown in Figure 3.9. The simulations that produced this map were for straight-row corn and the actual numbers should not be used for other crop/management alternatives.

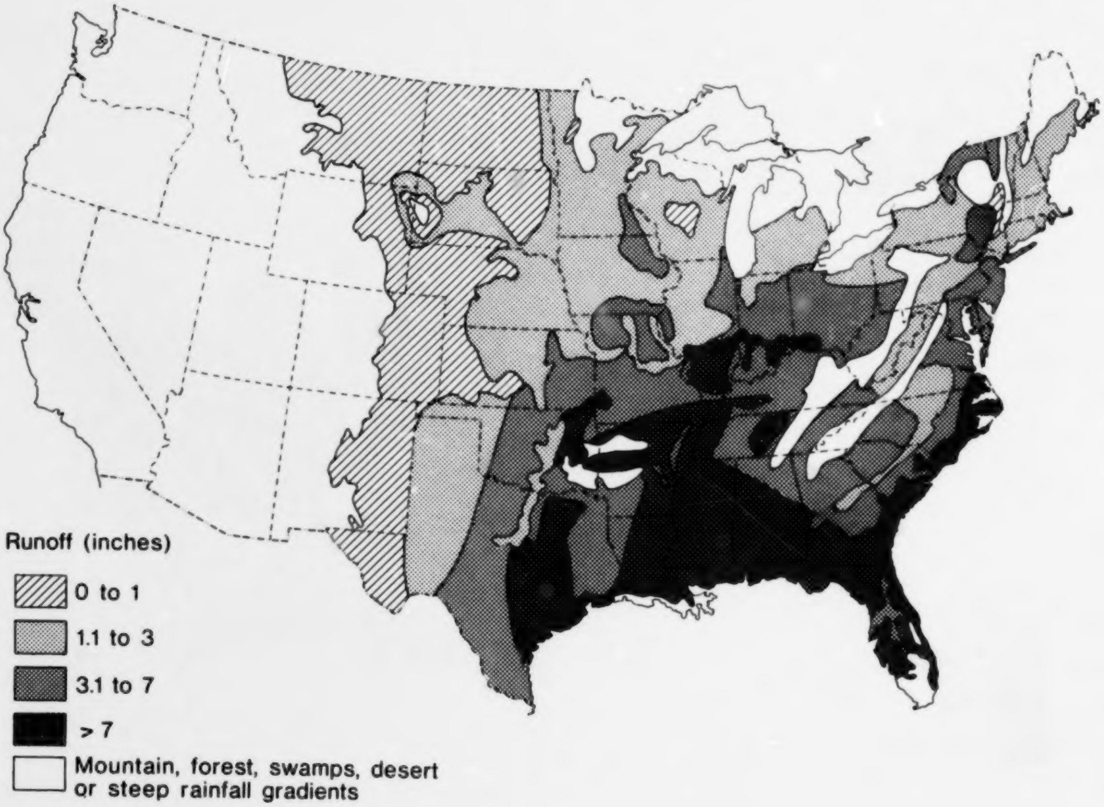

Runoff (inches)
▨ 0 to 1
1.1 to 3
3.1 to 7
> 7
Mountain, forest, swamps, desert or steep rainfall gradients

FIGURE 3.9. Average annual potential direct runoff (USDA, 1975).

This map does, however, give a comparison of the relative integrated impacts of the major watershed factors listed above on runoff, and as such, is useful for indicating potential pesticide runoff problem areas.

Figure 3.10 is taken from the same study. In this figure areas of potential contribution of cropland to watershed sediment yields have been classified as low, moderate, high or very high. The rating is computed by multiplying an erosion-potential index, which is based on soil erodibility and topographic information, by the percentage of cropland in each LRA. Thus it ranks the cropland contribution of sediment movement from the land surface to instream sediment loads. For a given field area this map may be misleading because a "high" ranking on the map may be as much due to cropland density as to erodible soil conditions.

A more direct way of ranking the erosion from fields in different physiographic areas is to make use of the Universal Soil Loss Equation, USLE (Wischmeier and Smith, 1978). The equation is:

$$X = R\ K\ LS\ C\ P \tag{3.1}$$

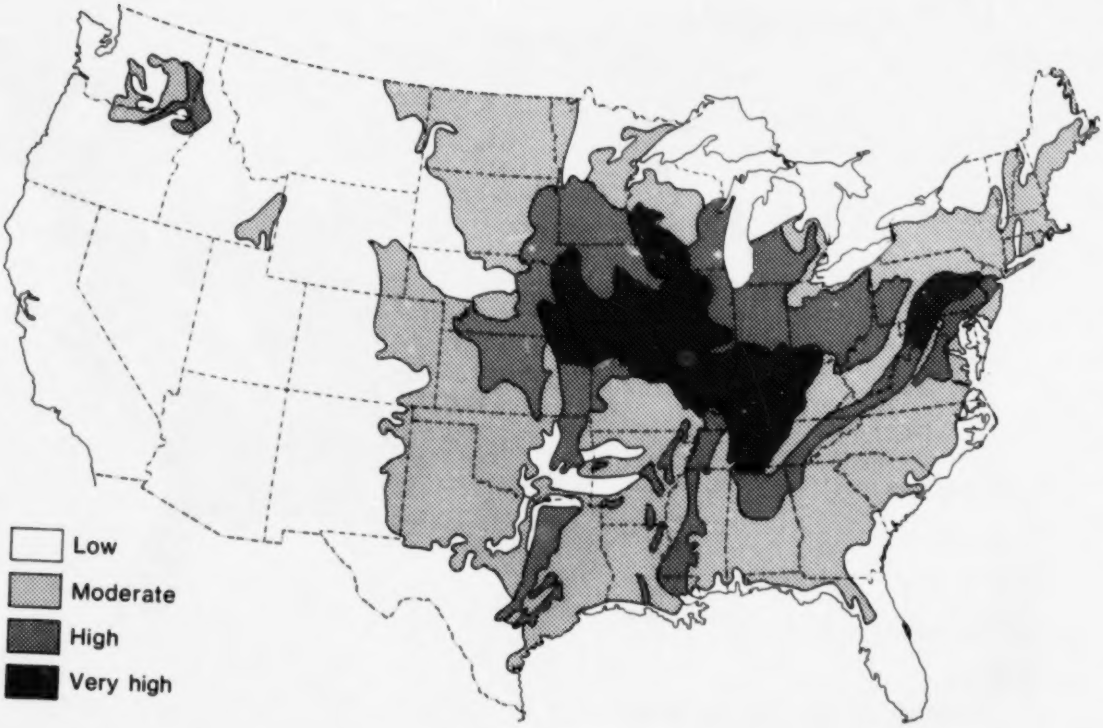


FIGURE 3.10. Relative potential contribution of cropland to watershed sediment yields (USDA, 1975).

where X = average annual soil loss in tons/acre-year

R = rainfall erosivity factor

K = soil erodibility factor

LS = slope-length factor

C = cover management factor

P = supporting practice factor

For the purposes of ranking sediment erosion potential based on climate, soil and topographical differences, the C and P factors can be ignored (i.e., set to unity). Thus the product RKLS alone can be used for ranking if the crop and supporting management practices are the same in each area.

The parameter R can be determined from the map in Figure 3.11. The maximum recommended value is 350. For the shaded area on the map the value should be adjusted to account for runoff from snowmelt (see USDA, 1974).

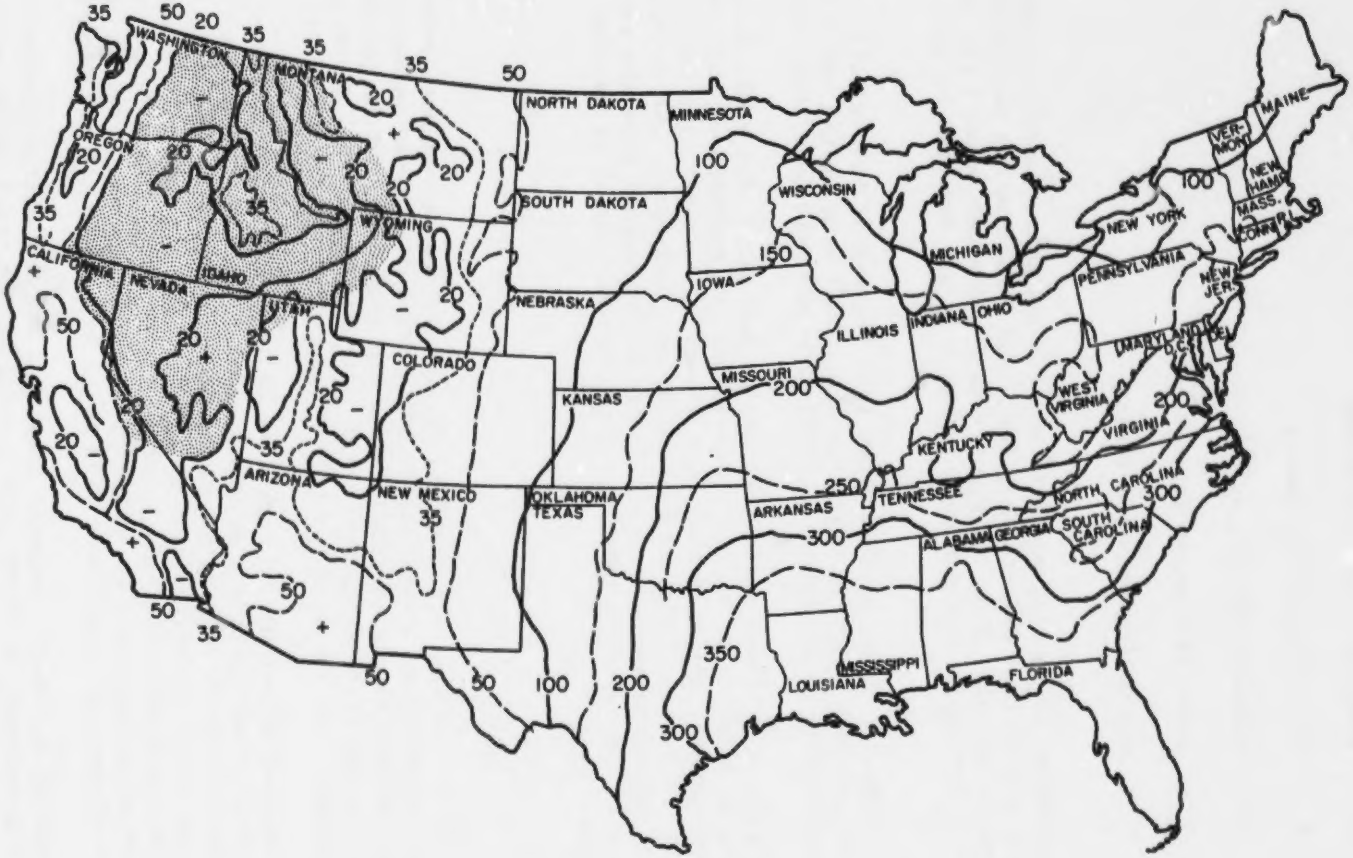
The soil erodibility factor 'K' can be determined for ranking purposes by looking up a value in Table 3.1, providing the predominant soil type and approximate organic matter content are known. In general, the soil organic matter content can be estimated by knowing soil nitrogen. The nitrogen content of unamended soils in the U.S. can be determined from the map in Figure 3.12. The approximate soil organic matter content is related to soil nitrogen by:

$$\%\ OM = 20\ (\%N) \qquad (3.2)$$

The final factor LS can be determined by knowing the approximate average length and steepness of slopes in the area. Table 3.2 gives values of the factor for various values of slope length and steepness. These parameters can be determined from topographic maps. In most cases, Soil Conservation Service personnel in the area may be a source of more accurate values.

The organic matter content has more of an effect on pesticide transport than simply modifying the erodibility of the soil. The adsorption of most pesticides can be related to the organic matter in the soil. Given the same pesticide in an area with higher soil organic matter, more of the pesticide would theoretically be adsorbed to the soil. Therefore, relatively more of the pesticide would be lost from the field area as a result of sediment transport and relatively less would be lost in the solution phase.

By looking at runoff, sediment loss, and organic matter content of the soils in a given area, a fairly good ranking of the areas can be made in order to determine which area might yield the better pesticide runoff data Base.


WASHINGTON
OREGON
CALIFORNIA
NEVADA
IDAHO
MONTANA
WYOMING
UTAH
ARIZONA
COLORADO
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
MINNESOTA
IOWA
MISSOURI
ARKANSAS
LOUISIANA
WISCONSIN
ILLINOIS
MICHIGAN
INDIANA
OHIO
KENTUCKY
TENNESSEE
MISSISSIPPI
ALABAMA
GEORGIA
FLORIDA
SOUTH CAROLINA
NORTH CAROLINA
VIRGINIA
WEST VIRGINIA
MARYLAND
D.C.
DEL
PENNSYLVANIA
NEW JER.
NEW YORK
CONN
R.I.
MASS.
VER-MONT
NEW HAMP.
MAINE
35
50
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35
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20
20
20
35
50
35
50
50
100
200
300
350
300
250
200
150
100
100
200
300

FIGURE 3.11. Average annual values of the rainfall-erosivity factor, R.

Table 3.1. INDICATIONS OF THE GENERAL MAGNITUDE OF THE SOIL-ERODIBILITY FACTOR, K

Texture class	Organic matter content		
	<0.5%	2%	4%
	K	K	K
Sand	0.05	0.03	0.02
Fine sand	.16	.14	.10
Very fine sand	.42	.36	.28
Loamy sand	.12	.10	.08
Loamy fine sand	.24	.20	.16
Loamy very fine sand	.44	.38	.30
Sandy loam	.27	.24	.19
Fine sandy loam	.35	.30	.24
Very fine sandy loam	.47	.41	.33
Loam	.38	.34	.29
Silt loam	.48	.42	.33
Silt	.60	.52	.42
Sandy clay loam	.27	.25	.21
Clay loam	.28	.25	.21
Silty clay loam	.37	.32	.26
Sandy clay	.14	.13	.12
Silty clay	.25	.23	.19
Clay		0.13-0.29	

(Source: USDA, 1975)

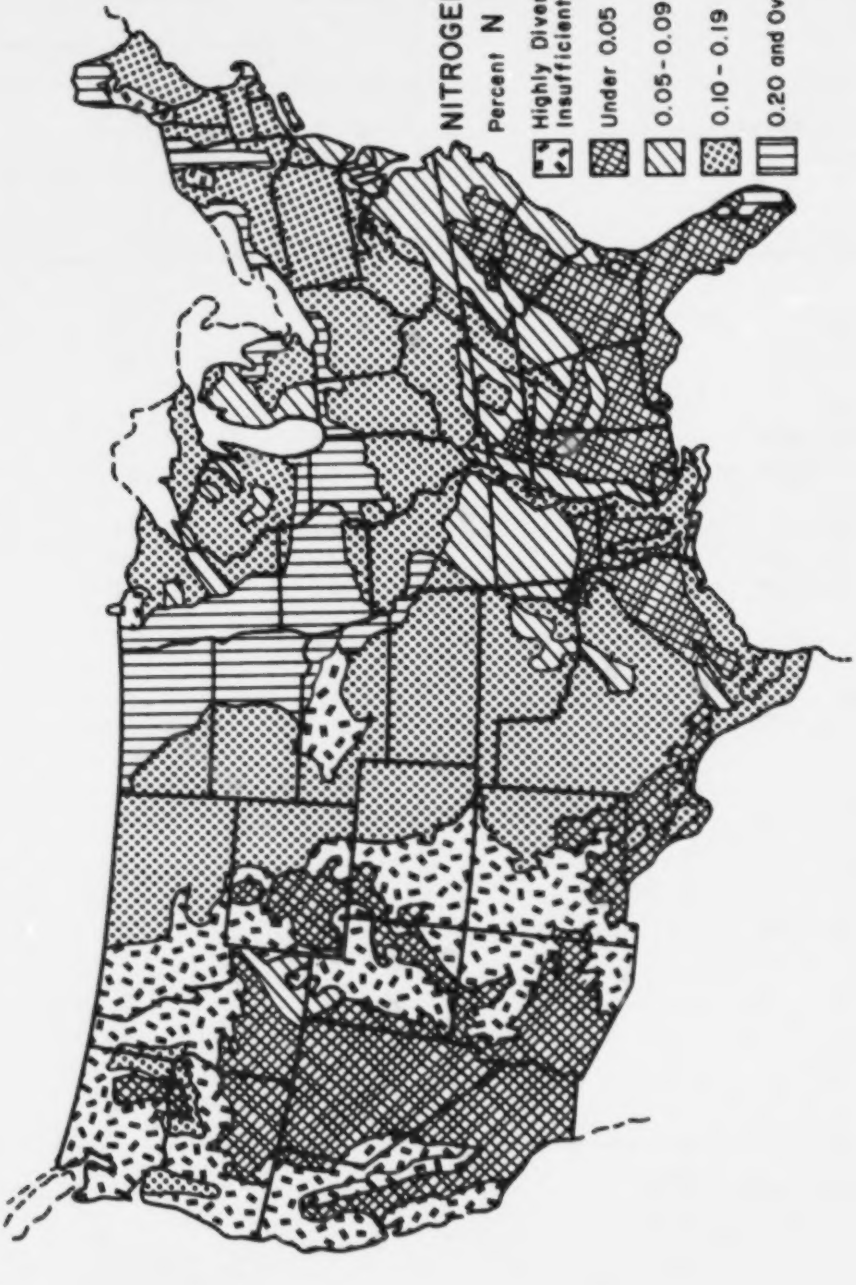
NITROGEN
Percent N
Highly Diverse Insufficient Data
Under 0.05
0.05 - 0.09
0.10 - 0.19
0.20 and Over

FIGURE 3.12. Percent nitrogen in surface foot of soil (Parker, 1946).

TABLE 3.2. VALUES OF THE USLE TOPOGRAPHIC FACTOR, LS, FOR SPECIFIED COMBINATIONS OF SLOPE LENGTH AND STEEPNESS (USDA, 1975)

% Slope	Slope length (feet)											
	25	50	75	100	150	200	300	400	500	600	800	1000
0.5	0.07	0.08	0.09	0.10	0.11	0.12	0.14	0.15	0.16	0.17	0.19	0.20
1	0.09	0.10	0.12	0.13	0.15	0.16	0.18	0.20	0.21	0.22	0.24	0.26
2	0.13	0.16	0.19	0.20	0.23	0.25	0.28	0.31	0.33	0.34	0.38	0.40
3	0.19	0.23	0.26	0.29	0.33	0.35	0.40	0.44	0.47	0.49	0.54	0.57
4	0.23	0.30	0.36	0.40	0.47	0.53	0.62	0.70	0.76	0.82	0.92	1.0
5	0.27	0.38	0.46	0.54	0.66	0.76	0.93	1.1	1.2	1.3	1.5	1.7
6	0.34	0.46	0.58	0.67	0.82	0.95	1.2	1.4	1.5	1.7	1.9	2.1
8	0.50	0.70	0.86	0.99	1.2	1.4	1.7	2.0	2.2	2.4	2.8	3.1
10	0.69	0.97	1.2	1.4	1.7	1.9	2.4	2.7	3.1	3.4	3.9	4.3
12	0.90	1.3	1.6	1.8	2.2	2.6	3.1	3.6	4.0	4.4	5.1	5.7
14	1.2	1.6	2.0	2.3	2.8	3.3	4.0	4.6	5.1	5.6	6.5	7.3
16	1.4	2.0	2.5	2.8	3.5	4.0	4.9	5.7	6.4	7.0	8.0	9.0
18	1.7	2.4	3.0	3.4	4.2	4.9	6.0	6.9	7.7	8.4	9.7	11.0
20	2.0	2.9	3.5	4.1	5.0	5.8	7.1	8.2	9.1	10.0	12.0	13.0
25	3.0	4.2	5.1	5.9	7.2	8.3	10.0	12.0	13.0	14.0	17.0	19.0
30	4.0	5.6	6.9	8.0	9.7	11.0	14.0	16.0	18.0	20.0	23.0	25.0
40	6.3	9.0	11.0	13.0	16.0	18.0	22.0	25.0	28.0	31.0	--	--
50	8.9	13.0	15.0	18.0	22.0	25.0	31.0	--	--	--	--	--
60	12.0	16.0	20.0	23.0	28.0	--	--	--	--	--	--	--

As an example let us say that we are interested in the application of a certain preemergent herbicide on corn. Let us assume that there are two major application areas of interest--the north-central portion of Iowa and the southern portion (coastal plain) of Georgia. According to Figure 3.9, the average annual potential direct runoff is 1.1 to 3 inches for north-central Iowa and >7 inches for southern Georgia. Figure 3.10 indicates that the relative potential contribution of cropland to watershed sediment yields in north-central Iowa is high, but moderate to low in southern Georgia.

Making use of the USLE, we can get a better picture of erosion potential. The value of R in north-central Iowa is approximately 150. The soil type is predominantly a silty clay loam. Soil nitrogen is generally 0.20% or greater. Therefore, the organic matter content of the soil is roughly 4%. Thus the soil erodibility 'K' should be approximately 0.26. For slopes of 2% and lengths of 1000 ft, LS would be about 0.40. Thus the RKLS product for an area in north-central Iowa might be:

$$\text{RKLS} = 150(.26)\,(.40) = 15.6 \text{ tons/ac-year} \qquad (3.3)$$

For the coastal plain of Georgia the R value is roughly 350. The soil nitrogen is under 0.05, therefore a limiting value for soil organic matter would be about 1.0%. Soils are generally loamy sands, therefore the 'K' parmeter is roughly 0.11. For a slope of 2% with a 300-ft slope length, LS = 0.28. Thus:

$$\text{RKLS} = 350\ (0.11)\ (0.28) = 10.8 \text{ tons/ac-year} \qquad (3.4)$$

Comparison of the two values indicates that, for the same crop with the same management practices, the erosion potential is likely to be higher in the north-central Iowa location than in the southern Georgia coastal plain area. Caution should be used when using such numbers as the sensitivity to slope, for instance, is quite high. If a 5% slope 300 feet in length is used for the Georgia coastal plain, the estimate becomes 36 tons/acre-year instead of 10.8. Thus we see that, although more runoff might be generated at the Georgia location, more sediment might be generated at the Iowa location. This coupled with the fact that organic matter is lower in the Georgia soils indicates that, for weakly adsorbed chemicals, more chemical runoff might be generated at the Georgia site while for more strongly adsorbed chemicals, the Iowa site might produce greater chemical runoff. If runoff model verification is the primary objective, the site producing greatest runoff would yield the most useful data set. Sites that produce no runoff are not useful for this purpose.

It may be, however, that the study is required in a certain area. In this case, steps 1 through 4 in the flow chart of Figure 3.1 would be omitted and the designer would go directly to the step in which candidate watersheds are selected.

3.1.2 Ranking Candidate Watersheds

Once a specific region is decided upon, there may be several candidate watersheds that can be identified. This done, they should be ranked according to logistical factors that should have bearing on the final selection. These ranking factors include:

- Landowner/Manager Cooperation
- Capability for Growing Crop of Choice
- Capability to Implement Management Practice of Choice
- Homogeneity of the Watershed
- Accessibility
- Existence of Available Permanently Installed Equipment
- Location with Respect to Environmentally Sensitive Areas
- Presence of Endangered Species

The first factor that should be considered is the cooperation of the landowner or manager to provide access to the site. In addition, he must be willing to have the equipment installed and the watershed must be capable of supporting the desired management practices and the crop of choice. The watershed should be in an area in which it is possible to install equipment easily. A power source is a consideration for some equipment. It should also be possible to get to the watershed quickly in case of equipment failures or for other reasons.

Watersheds that have permanently installed equipment such as runoff weirs and those that have associated historical data should be given significant priority in the ranking process especially if other selection criteria are satisfied.

Test watersheds should not be located so that pesticide drift or runoff would migrate into environmentally sensitive areas. The designer also should avoid areas having populations of endangered species.

Homogeneity of the watershed soils and relief should be considered. Obviously, the cost of sampling to characterize the system and collect residue data will increase with increasing diversity in the watershed. In addition, results of the study from more homogeneous areas will allow for more facile interpretation of the data collected.

3.2 SITE DESCRIPTION

The accurate acquisition and reporting of information describing the watershed is an important step in the data collection process. It serves a function beyond simply providing introductory materials for a report. In many cases, watershed response can be explained by having knowledge of conditions that exist or have existed in the area.

A generic site description should include information in the following categories:

- Location and size
- Climate (meteorology)
- Topography
- Soils
- Geology
- History

3.2.1 Location and Size

The approximate latitude and longitude of the watershed should be determined. Also, other descriptive qualities should be given about the location (e.g., the watershed is in the Atlantic Coastal Flatwoods Area). Some agencies like the Dept. of Agriculture and the Dept. of Commerce have divided the United States into provinces or areas that are considered to be homogeneous with regard to their particular data acquisition activities. If these qualifiers are also given, this knowledge may aid in the retrieval of information by these agencies. Examples are the Dept. of Agriculture Soil Conservation Service Land Resource Areas (LRAs) or the Dept. of Commerce Climatic Divisions.

The size of the watershed should be accurately reported. Improper reporting of watershed area can lead to bias in water and material balances. In general it is more accurate to determine areas through surveying directly (if this is possible) as opposed to planimetering from topographic maps.

Maps showing the location and size of the watershed should be prepared. Any prominent features in the watershed should be recorded on these maps.

Watershed area of 0.5 ha to 2.0 ha should be considered a minimally acceptable size to avoid small scale effects that could negate the extent to which the site would be considered 'representative' of the region. Larger sites are preferred. The upper limit of the site will be controlled by the costs of sampling large areas. Model capabilities will also affect the allowable size of the site.

3.2.2 Climate

General climatic characteristics in the area should be reported. Means and extremes of precipitation, snowfall, pan evaporation and temperature are frequently useful if they are known. This information can be obtained from several sources. The best source is probably the Climatic Atlas of the United States (U.S. Dept. of Commerce, 1968). Another source that may contain additional useful information is the Water Atlas of the United States (Geraghty et al., 1973).

3.2.3 Topography

Good topographical information is essential for watershed hydrologic and transport modeling. Elevation above mean sea level of the watershed outlet or stream gaging station should be reported. Usually, reliable topographic maps can be obtained from the U.S. Geological Survey for larger areas. If the watershed is small, surveying of the area may be necessary. Survey information should be adequate to determine field slopes. This information should be as accurate as possible, because of the dependency of runoff and sediment transport, especially the latter, on slope.

Topographical and drainage alterations by man should be noted (e.g., land leveling, terracing, grassed waterways, tile drainage). In these cases, dimensions of terraces, slopes and widths of runoff diversions, locations and depths of tile drains, etc. should be noted. Topographic maps showing general drainage patterns of water and showing source and deposition areas of sediment can be very useful.

3.2.4 Soils

Spatial mapping of the surface and subsurface soils should be performed. In many cases, this mapping has been done by the Soil Conservation Service and is available in county soil surveys. If not, the mapping should be done by a qualified soil scientist. Once these soils are identified, erosional information such as erodibility ('K' of the Universal Soil Loss Equation) should be provided if available. Soil cores for each soil series in the watershed should be taken and analyzed. Typical pedon information should be recorded as shown in Table 3.3. Location of the soil cores taken should also be recorded. More quantitative information is also needed as discussed later in this chapter (Section 3.5). An example of a map that shows information concerning soils and topography is shown in Figure 3.13.

3.2.5 Geology

Geologic foundation materials should be described paying special attention to their type and capability to transmit water. Types of and depths of impermeable layers are of interest, especially if they are relatively shallow. The impact of shallow ground water on direct surface

TABLE 3.3. TYPICAL SOIL PEDON DESCRIPTION (Smith et al., 1978)

Soil:	Cecil sandy loam*
Classification:	Typic hapludult, clayey, kaolinitic, thermic
Location:	Watkinsville, Georgia, Southern Piedmont Conservation Research Center, 10 meters southeast of Watershed P3
AP 0-20 cm	Light brown (7.5YR 6/4 dry; 5YR 5/4 moist) sandy loam; weak fine granular structure; moderately friable, moist; gradual smooth boundary; many fine roots.
B1 20-30 cm	Light red (2.5YR 6/6 dry) to red (2.5YR 4/6 moist) sandy clay loam; weak medium subangular blocky structure; moderately friable moist; gradual wavy boundary, few coarse sand grains, few medium roots.
B21t 30-64 cm	Red (2.5 5/6 dry; 2.5YR 4/6 moist) clay; moderate medium subangular blocky structure; moderately friable to firm moist; gradual wavy boundary; few coarse sand grains; few medium roots.
B22t 64-102 cm	Red (2.5YR 5/6 dry; 2.5YR 4/6 moist) clay; moderate medium subangular blocky structure; moderately friable moist; gradual wavy boundary; few mica flakes, few quartz gravel.
B3 102-132 cm	Red (2.5YR 5/6 dry; 2.5YR 4/6 moist) clay loam; moderate medium subangular blocky structure; moderately friable moist; common mica flakes; few schist and gneiss fragments.
C 132+ cm	Weathered schist and gneiss material.

*Described by George C. Brock and C. L. McIntyre, U.S. Soil Conservation Service, Athens, GA.

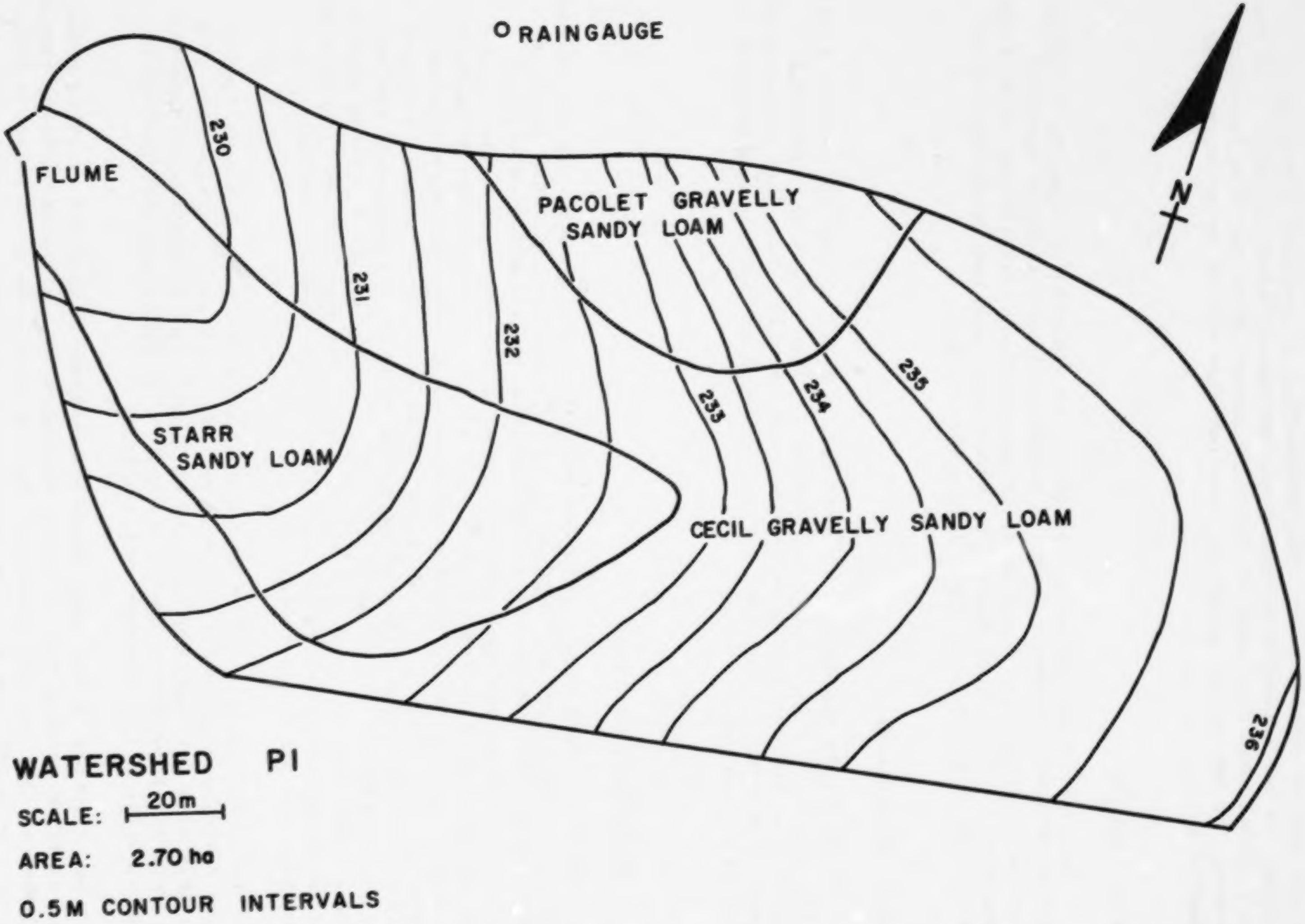
RAINGAUGE
N
FLUME
PACOLET GRAVELLY
SANDY LOAM
STARR
SANDY LOAM
CECIL GRAVELLY SANDY LOAM
230
231
232
233
234
235
236
WATERSHED P1
SCALE: 20m
AREA: 2.70 ha
0.5M CONTOUR INTERVALS

FIGURE 3.13. Soils and topography, watershed P1, Watkinsville, GA (Smith et al., 1978).

runoff can be considerable. The possibility of regional ground water inflows to the watershed system should be investigated, especially if there is a chance that discharge of this flow occurs above the flow recording device. To the extent possible, such behavior should be documented and quantified.

3.2.6 History

The history of the watershed should be recorded to a practical extent noting such occurrences as natural disasters (e.g., fires or extended periods of flooding), the history of cultivation, installation of drainage alterations (e.g., tile drains) or structures, and the recent history of fertilizer and pesticide applications (if known).

3.2.7 Photographs

Photographs are useful for providing a hard copy of the overall field site, installed instrumentation, various tillage operations, pesticide application and monitoring techniques, and overall field crop canopy development with time (see Section 3.13). Selected photographs are valuable to include in the project report.

3.3 MEASUREMENT OF RUNOFF

Surface runoff occurs when the rainfall intensity and duration exceeds the infiltration rate and depression storage of the soil. The amount of runoff produced, however, is a function of site size, antecedent soil moisture content, soil permeability, vegetation, evaporation rate, slope and surface roughness (Wauchope et al., 1977). The pesticide concentration in runoff is affected by these properties as well as the properties of the pesticide including water solubility, degradation rate in soil, sorption to soil and sediment and method of application (plant foliage, soil surface or soil incorporated) (Wauchope et al., 1977). The flow from a field site is intermittent and can vary from low to high flows with varying time intervals (few minutes to several hours) depending on the rainfall intensity and duration, and site characteristics.

Prior to installation of equipment to measure surface runoff from a given field, several decisions must be made, such as: (1) selection of a suitable site for runoff monitoring equipment, (2) estimation of expected rainfall and flow rates, and (3) selection of monitoring equipment (i.e., flumes, water stage recorder, and sampler).

As indicated in the site selection section, watersheds or field sites with existing permanently installed equipment such as runoff flumes, samplers and weather station with historical records should be given priority consideration provided they meet the objective of the study. Several instrumented sites are currently in use in various locations within the United States.

For information regarding availability, it is suggested that contacts be made with the USDA agricultural experiment station and state universities (i.e., agronomy and agricultural engineering departments). If an existing site cannot be located for use, then the selection of a new site should begin. First, in the process of selecting a suitable site to study runoff of pesticides, one must conduct site visits and determine whether runoff does occur. Secondly, it must be determined that the field has a drainage pattern that converges to a central draw or drainage channel and outside boundaries are well established. To ensure that runoff water from other areas does not enter the site, a soil berm (embankment) or dike can be established on the outside boundary of the field. In predominantly level geographic areas where well defined drainage channels are not apparent, it may be necessary to construct a system of barriers to direct runoff to a central collection point. Depending on the specific field situation, these might be elaborate metal or concrete barriers or simple soil terraces.

3.3.1 Equipment for Runoff Flow Measurements

Devices for monitoring flow commonly consist of various type flumes and weirs. For field-scale runoff studies involving intermittent storms, H-type measuring flumes (H and HL type) are appropriate, see Figure 3.14. These flumes have been used successfully in previous runoff studies. Weirs, on the other hand, are inappropriate for monitoring intermittent flows (i.e., ponding conditions are created as well as sediment deposition).

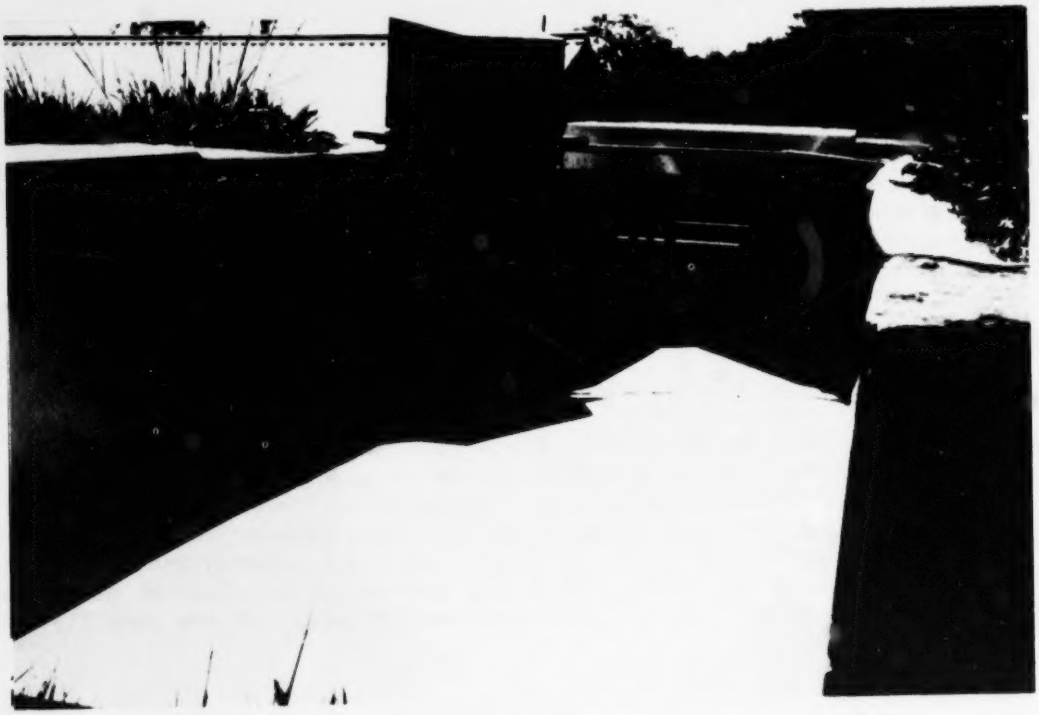

FIGURE 3.14. H-type flume with sloping floor approach.

H-type flumes have the capability of measuring a wide range of flow rates with a high degree of accuracy. They are more accurate at lower flows as compared to other types (i.e., Parshall). When high sediment concentrations are present, they are subject to deposition problems, which can be minimized by using a sloping false floor (Wauchope et al., 1977, 1985). Flumes are designed to be self-cleaning and are essentially maintenance free after installation (Grant, 1981). Calibration data for various size standard flumes are tabulated in Tables 3.4 and 3.5.

Commercially available prefabricated flumes are usually made of Fiberglass® material or plastic materials. The use of these flumes in pesticide runoff studies is questionable because of the high affinity of Fiberglass® material or plastic for sorbing some pesticides. The impact of the flume material on pesticide concentrations is difficult to estimate, but the potential sorption problem should be recognized. In most cases, the problem can be minimized or eliminated by either sampling upstream from the flow measurement device or by constructing a 316 type stainless steel flume designed according to specification by USDA (1979). It is important that the flume be built to exact specifications. Previous pesticide runoff studies (Smith et al, 1978; Johnson and Baker, 1982-1984; Ellis et al., 1977) report the use of stainless steel flumes. In addition to a stainless steel flume, the approach box should also be made of stainless steel. The approach box is located on the upstream side of the flume and is useful for mixing runoff during sampling. The advantages of using the stainless steel flume for pesticide runoff studies outweigh the convenience of other materials.

3.3.2 Water Stage Measurement

To determine the rate of flow and runoff volume, a continuous water stage record for depth of flow (stage or head) with time during the event is required. This is obtained using a water stage recorder in conjunction with a stilling well attached to the flume. A typical setup is shown in Figure 3.15. A wide range of water level recorders are commercially available that utilize electric, spring-wound or weight-driven clocks. An important advantage of the mechanical types is that they are not subject to failure due to power outages that may occur during storm events. Models are available that can be set to operate over intervals of 6 to 192 hours. Multiple units can be installed to ensure that stage height data are not lost due to recorder failure. Johnson and Baker (1982) installed recorders on opposite sides of the flume. The stage record from the water level recorders (derived from breakpoint values or at even time intervals) are converted into rates of flow, i.e., discharge in ft^3/sec, by using the rating table for the type flume being used (see rating Tables 3.4 and 3.5). The water stage recorders should be enclosed in an appropriate shelter. The shelter can be hinged to allow easy access for maintenance of the recorder and changing of charts. For additional information see USDA (1979).

TABLE 3.4. RATING TABLES FOR H FLUME (USDA, 1979)

[Discharge in cubic feet per second]

FLUME 0.5 FOOT DEEP

Head (ft)	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0	0	(1)	0.0004	0.0009	0.0016	0.0024	0.0035	0.0047	0.0063	0.0080
0.1	.0101	.0122	.0146	.0173	.0202	.0233	.0267	.0304	[illegible]	.0385
0.2	.0431	.0479	.0530	.0585	.0643	.0704	.0767	.0834	.0905	.0979
0.3	.1057	.1139	.1224	.1314	.1407	.1505	.1607	.1713	.1823	.1938
0.4	.205	.217	.230	.244	.257	.271	.285	.300	.315	.331

FLUME 0.75 FOOT DEEP

0	0	(1)	0.0006	0.0013	0.0022	0.0032	0.0046	0.0061	0.0080	0.0101
0.1	.0126	.0151	.0179	.0210	.0242	.0278	.0317	.0358	.0403	.0451
0.2	.0501	.0555	.0612	.0672	.0735	.0802	.0872	.0946	.1023	.1104
0.3	.119	.128	.137	.146	.156	.167	.177	.188	.199	.211
0.4	.224	.237	.250	.263	.277	.291	.306	.321	.337	.353
0.5	.370	.388	.406	.424	.443	.462	.482	.502	.523	.544
0.6	.566	.588	.611	.635	.659	.683	.708	.734	.760	.786
0.7	.813	.841	.869	.898	.927	.957	----------	----------	----------	----------

FLUME 1.0 FOOT DEEP

Head (ft)	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0	0	(1)	0.0007	0.0017	0.0027	0.0040	0.0056	0.0075	0.0097	0.0122
0.1	.0150	.0179	.0211	.0246	.0284	.0324	.0367	.0413	.0462	.0515
0.2	.0571	.0630	.0692	.0758	.0827	.0900	.0976	.1055	.1138	.1226
0.3	.132	.141	.151	.161	.172	.183	.194	.206	.218	.231
0.4	.244	.257	.271	.285	.300	.315	.331	.347	.364.	.381
0.5	.398	.416	.434	.453	.472	.492	.512	.533	.554	.576
0.6	.598	.621	.644	.668	.692	.717	.743	.769	.796	.823
0.7	.851	.880	.909	.939	.969	1.000	1.031	1.063	1.096	1.129
0.8	1.16	1.20	1.23	1.27	1.30	1.34	1.38	1.41	1.45	1.49
0.9	1.53	1.57	1.61	1.66	1.70	1.74	1.78	1.83	1.87	1.92

FLUME 1.5 FEET DEEP

0	0	(1)	0.0011	0.0023	0.0039	0.0057	0.0078	0.0103	0.0131	0.0164
0.1	.0200	0.0237	.0276	.0319	.0365	.0414	.0467	.0523	.0582	.0645
0.2	.0711	.0780	.0854	.0931	.1011	.1095	.1183	.1275	.1371	.1470
0.3	.157	.168	.179	.191	.203	.215	.228	.241	.255	.269
0.4	.283	.298	.314	.330	.346	.363	.380	.398	.416	.435
0.5	.454	.473	.493	.514	.535	.557	.579	.601	.624	.648
0.6	.672	.697	.722	.747	.773	.800	.827	.855	.883	.912
0.7	.942	.972	1.002	1.033	1.065	1.097	1.130	1.163	1.197	1.231
0.8	1.27	1.30	1.34	1.38	1.41	1.45	1.49	1.53	1.57	1.61
0.9	1.65	1.69	1.73	1.78	1.82	1.86	1.91	1.95	2.00	2.05
1.0	2.09	2.14	2.19	2.24	2.30	2.35	2.40	2.45	2.50	2.56
1.1	2.61	2.67	2.73	2.78	2.84	2.90	2.96	3.02	3.08	3.14
1.2	3.20	3.27	3.33	3.39	3.46	3.52	3.59	3.66	3.73	3.80
1.3	3.87	3.94	4.01	4.08	4.15	4.22	4.30	4.37	4.45	4.52
1.4	4.60	4.68	4.76	4.84	4.92	5.00	5.08	5.16	5.24	5.33

See footnotes at end of table.

TABLE 3.4 (Cont'd). RATING TABLES FOR H FLUME (USDA, 1979)

[Discharge in cubic feet per second]

FLUME 2.0 FEET DEEP

Head (ft)	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0	0	(2)	0.0014	0.0031	0.0050	0.0073	0.0100	0.0130	0.0166	0.0205
0.1	.0248	0.0293	.0341	.0392	.0447	.0505	.0567	.0632	.0701	.0774
0.2	.0850	.0930	.1015	.1103	.1195	.1290	.1390	.1494	.1602	.1714
0.3	.183	.195	.207	.220	.234	.248	.262	.276	.291	.307
0.4	.323	.339	.356	.374	.392	.410	.429	.448	.468	.488
0.5	.509	.530	.552	.574	.597	.620	.644	.668	.693	.719
0.6	.745	.771	.798	.826	.854	.882	.911	.941	.971	1.002
0.7	1.03	1.07	1.10	1.13	1.16	1.20	1.23	1.27	1.30	1.34
0.8	1.38	1.42	1.46	1.49	1.53	1.57	1.62	1.66	1.70	1.74
0.2	1.78	1.83	1.87	1.92	1.96	2.01	2.06	2.10	2.15	2.20
1.0	2.25	2.30	2.35	2.40	2.45	2.51	2.56	2.62	2.67	2.73
1.1	2.78	2.84	2.90	2.96	3.02	3.08	3.14	3.20	3.26	3.32
1.2	3.38	3.45	3.51	3.58	3.65	3.71	3.78	3.85	3.92	3.99
1.3	4.06	4.13	4.20	4.28	4.35	4.43	4.50	4.58	4.66	4.74
1.4	4.82	4.90	4.98	5.06	5.14	5.23	5.31	5.40	5.48	5.57
1.5	5.65	5.74	5.83	5.92	6.01	6.11	6.20	6.29	6.38	6.48
1.6	6.58	6.67	6.77	6.87	6.97	7.07	7.17	7.27	7.37	7.47
1.7	7.58	7.68	7.79	7.90	8.00	8.11	8.22	8.33	8.44	8.56
1.8	8.67	8.78	8.90	9.01	9.13	9.24	9.36	9.48	9.60	9.72
1.9	9.85	9.97	10.09	10.21	10.34	10.47	10.60	10.72	10.85	10.98

FLUME 2.5 FEET DEEP

Head (ft)	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0	0	(20	0.0018	0.0038	0.0061	0.0089	0.0121	0.0158	0.0200	0.0247
0.1	.0298	0.0350	.0406	.0465	.0528	.0595	.0666	.0741	.0820	.0903
0.2	.0990	.1081	.1176	.1275	.1379	.1486	.1597	.1713	.1834	.1960
0.3	.209	.222	.236	.250	.265	.280	.296	.312	.328	.345
0.4	.363	.381	.399	.418	.437	.457	.478	.499	.520	.542
0.5	.564	.587	.611	.635	.659	.684	.710	.736	.763	.790
0.6	.818	.846	.875	.904	.934	.965	.996	1.027	1.059	1.092
0.7	1.13	1.16	1.19	1.23	1.27	1.30	1.34	1.38	1.41	1.45
0.8	1.49	1.53	1.57	1.61	1.65	1.70	1.74	1.78	1.83	1.87
0.9	1.92	1.96	2.01	2.06	2.11	2.16	2.21	2.26	2.31	2.36
1.0	2.41	2.46	2.51	2.57	2.62	2.68	2.74	2.79	2.85	2.91
1.1	2.97	3.03	3.09	3.15	3.21	3.27	3.33	3.40	3.46	3.53
1.2	3.59	3.66	3.73	3.80	3.86	3.93	4.00	4.07	4.15	4.22
1.3	4.29	4.37	4.44	4.52	4.59	4.67	4.75	4.82	4.90	4.98
1.4	5.06	5.15	5.23	5.31	5.39	5.48	5.56	5.65	5.74	5.82
1.5	5.91	6.00	6.09	6.18	6.27	6.37	6.46	6.55	6.65	6.75
1.6	6.84	6.94	7.04	7.14	7.24	7.34	7.45	7.55	7.66	7.76
1.7	7.86	7.97	8.08	8.19	8.30	8.41	8.53	8.64	8.75	8.87
1.8	8.98	9.10	9.22	9.34	9.45	9.57	9.70	9.82	9.94	10.06
1.9	10.2	10.3	10.4	10.6	10.7	10.8	11.0	11.1	11.2	11.4

See footnotes at end of table.

TABLE 3.4 (Cont'd). RATING TABLES FOR H FLUME (USDA, 1979)

[Discharge in cubic feet per second]

FLUME 2.5 FEET DEEP—Con.

Head (ft)	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
2.0	11.5	11.6	11.8	11.9	12.0	12.2	12.3	12.5	12.6	12.7
2.1	12.9	13.0	13.2	13.3	13.5	13.6	13.8	13.9	14.1	14.2
2.2	14.4	14.5	14.7	14.8	15.0	15.1	15.3	15.5	15.6	15.8
2.3	16.0	16.1	16.3	16.4	16.6	16.8	17.0	17.1	17.3	17.5
2.4	17.6	17.8	18.0	18.2	18.3	18.5	18.7	19.1	19.1	19.2
FLUME 3.0 FEET DEEP										
0	0	(2)	0.0021	0.0045	0.0073	0.0105	0.0143	0.0186	0.0234	0.0288
0.1	.0347	0.0407	.0471	.0538	.0610	.0686	.0766	.0851	.0939	.1032
0.2	.113	.123	.134	.145	.156	.168	.180	.193	.207	.220
0.3	.234	.249	.264	.280	.296	.312	.329	.347	.365	.383
0.4	.402	.421	.441	.462	.483	.504	.526	.549	.572	.596
0.5	.620	.644	.669	.695	.721	.748	.775	.803	.832	.861
0.6	.890	.920	.951	.982	1.014	1.047	1.080	1.113	1.147	1.182
0.7	1.22	1.25	1.29	1.33	1.36	1.40	1.44	1.48	1.52	1.56
0.8	1.60	1.65	1.69	1.73	1.78	1.82	1.86	1.91	1.96	2.00
0.9	2.05	2.10	2.15	2.20	2.25	2.30	2.35	2.41	2.46	2.51
1.0	2.57	2.62	2.68	2.73	2.79	2.85	2.91	2.97	3.03	3.09
1.1	3.15	3.21	3.27	3.34	3.40	3.46	3.53	3.60	3.66	3.73
1.2	3.80	3.87	3.94	4.01	4.08	4.15	4.23	4.30	4.37	4.45
1.3	4.53	4.60	4.68	4.76	4.84	4.92	5.00	5.08	5.16	5.24
1.4	5.33	5.41	5.50	5.58	5.67	5.76	5.84	5.93	6.02	6.11
1.5	6.20	6.30	6.39	6.48	6,58	6.67	6.77	6.87	6.96	7.06
1.6	7.16	7.26	7.36	7.47	7.57	7.67	7.78	7.88	7.99	8.10
1.7	8.20	8.31	8.42	8.53	8.64	8.75	8.87	8.98	9.10	9.21
1.8	9.33	9.45	9.56	9.68	9.80	9.92	10.05	10.17	10.29	10.41
1.9	10.5	10.7	10.8	10.9	11.0	11.2	11.3	11.4	11.6	11.7
2.0	11.9	12.0	12.1	12.3	12.4	12.6	12.7	12.8	13.0	13.1
2.1	13.3	13.4	13.6	13.7	13.9	14.0	14.2	14.3	14.5	14.6
2.2	14.8	14.9	15.1	15.3	15.4	15.6	15.7	15.9	16.1	16.2
2.3	16.4	16.6	16.7	16.9	17.1	17.2	17.4	17.6	17.8	17.9
2.4	18.1	18.3	18.5	18.7	18.8	19.0	19.2	19.4	19.6	19.8
2.5	19.9	20.1	20.3	20.5	20.7	20.9	21.1	21.3	21.5	21.7
2.6	21.9	22.1	22.3	22.5	22.7	22.9	23.1	23.3	23.5	23.7
2.7	23.9	24.1	24.3	24.5	24.7	24.9	25.2	25.4	25.6	25.8
2.8	26.0	26.2	26.5	26.7	26.9	27.1	27.4	27.6	27.8	28.0
2.9	28.3	28.5	28.7	28.9	29.2	29.4	29.7	29.9	30.1	30.4

TABLE 3.4 (Cont'd). RATING TABLES FOR H FLUME (USDA, 1979)

[Discharge in cubic feet per second]

FLUME 4.5 FEET DEEP

Head (ft)	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0	0	(²)	0.0031	0.0066	0.0106	0.0154	0.0208	0.0269	0.0337	0.0413
0.1	.0496	0.0578	.0666	.0758	.0855	.0959	.1067	.1180	.1298	.1420
0.2	.155	.168	.182	.196	.211	.226	.242	.259	.276	.293
0.3	.311	.330	.349	.368	.388	.409	.430	.452	.474	.497
0.4	.520	.544	.569	.594	.620	.646	.673	.700	.728	.756
0.5	.785	.815	.845	.876	.907	.939	.972	1.005	1.039	1.073
0.6	1.11	1.14	1.18	1.122	1.25	1.29	1.33	1.38	1.41	1.45
0.7	1.49	1.53	1.58	1.62	1.66	1.71	1.75	1.80	1.84	1.89
0.8	1.94	1.99	2.04	2.09	2.14	2.19	2.24	2.29	2.35	2.40
0.9	2.45	2.51	2.56	2.62	2.68	2.74	2.79	2.85	2.91	2.98
1.0	3.04	3.10	3.16	3.22	3.29	3.35	3.42	3.49	3.55	3.62
1.1	3.69	3.76	3.83	3.90	3.97	4.04	4.12	4.19	4.27	4.34
1.2	4.42	4.50	4.58	4.65	4.73	4.81	4.89	4.98	5.06	5.14
1.3	5.22	5.31	5.39	5.48	5.57	5.66	5.74	5.83	5.92	6.02
1.4	6.11	6.20	6.29	6.39	6.48	6.58	6.68	6.77	6.87	6.97
1.5	7.07	7.17	7.27	7.37	7.48	7.59	7.69	7.80	7.90	8.01
1.6	8.12	8.23	8.34	8.45	8.56	8.68	8.79	8.90	9.02	9.14
1.7	9.25	9.37	9.49	9.61	9.73	9.85	9.98	10.10	10.22	10.35
1.8	10.5	10.6	10.7	10.8	11.0	11.1	11.2	11.4	11.5	11.6
1.9	11.8	11.9	12.0	12.2	12.3	12.5	12.6	12.8	12.9	13.0
2.0	13.2	13.3	13.5	13.6	13.7	13.9	14.1	14.2	14.4	14.5
2.1	14.7	14.8	15.0	15.2	15.3	15.5	15.6	15.8	15.9	16.1
2.2	16.3	16.4	16.6	16.8	16.9	17.1	17.3	17.4	17.6	17.8
2.3	18.0	18.1	18.3	18.5	18.7	18.8	19.0	19.2	19.4	19.6
2.4	19.7	19.9	20.1	20.3	20.5	20.7	20.9	21.0	21.2	21.4
2.5	21.6	21.8	22.0	22.2	22.4	22.6	22.8	23.0	23.2	23.4
2.6	23.6	23.8	24.0	24.2	24.4	24.6	24.9	25.1	25.3	25.5
2.7	25.7	25.9	26.1	26.4	26.6	26.8	27.0	27.2	27.4	27.7
2.8	27.9	28.1	28.4	28.6	28.8	29.0	29.3	29.5	29.7	30.0
2.9	30.2	30.4	30.7	30.9	31.2	31.4	31.7	31.9	32.2	32.4
3.0	32.7	32.9	33.2	33.4	33.7	33.9	34.2	34.4	34.7	35.0
3.1	35.2	35.5	35.8	36.0	36.3	36.6	36.8	37.1	37.4	37.7
3.2	37.9	38.2	38.5	38.8	39.0	39.3	39.6	39.9	40.2	40.5
3.3	40.8	41.2	41.3	41.6	41.9	42.2	42.5	42.8	43.1	43.4
3.4	43.7	44.0	44.3	44.6	44.9	45.2	45.5	45.8	46.1	46.4
3.5	46.8	47.1	47.4	47.7	48.0	48.3	48.6	49.0	49.3	49.6
3.6	49.9	50.3	50.6	50.9	51.2	51.6	51.9	52.2	52.6	52.9
3.7	53.2	53.6	53.9	54.3	54.6	54.9	55.3	55.6	56.0	56.3
3.8	56.7	57.0	57.4	57.7	58.1	58.4	58.8	59.2	59.5	59.9
3.9	60.2	60.6	61.0	61.3	61.7	62.1	62.4	62.8	63.2	63.6
4.0	63.9	64.3	64.7	65.1	65.4	65.8	66.2	66.6	67.0	67.4
4.1	67.8	68.2	68.5	68.9	69.3	69.7	70.1	70.5	70.9	71.3
4.2	71.7	72.1	72.5	72.9	73.3	73.8	74.2	74.6	75.0	75.4
4.3	75.8	76.2	76.6	77.1	77.5	77.9	78.3	78.8	79.2	79.6
4.4	80.0	80.5	80.9	81.3	81.8	82.2	82.6	83.1	83.5	84.0

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[1] Rating derived from tests made by the Soil Conservation Service at the Hydraulic Laboratory of the National Bureau of Standards using 1-on-8 sloping false floor.

[2] Trace.

TABLE 3.5. RATING TABLES FOR 4-FOOT HL FLUME (USDA, 1975)

[Discharge in cubic feet per second]

Head (feet)	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0	0	(2)	0.005	0.012	0.020	0.029	0.039	0.050	0.062	0.075
0.1	.089	0.103	.119	.135	.152	.170	.190	.211	.232	.255
0.2	.278	.302	.327	.352	.378	.405	.434	.465	.497	.530
0.3	.565	.600	.635	.670	.705	.740	.780	.820	.860	.900
0.4	.940	.982	1.03	1.08	1.12	1.17	1.22	1.27	1.32	1.37
0.5	1.42	1.48	1.53	1.59	1.64	1.70	1.76	1.82	1.88	1.94
0.6	2.01	2.07	2.14	2.21	2.28	2.35	2.42	2.49	2.56	2.64
0.7	2.71	2.79	2.87	2.95	3.03	3.11	3.19	3.28	3.36	3.44
0.8	3.53	3.61	3.70	3.79	3.88	3.98	4.08	4.18	4.28	4.38
0.9	4.48	4.58	4.68	4.79	4.90	5.01	5.12	5.23	5.34	5.45
1.0	5.56	5.68	5.80	5.92	6.04	6.16	6.28	6.40	6.52	6.64
1.1	6.76	6.89	7.02	7.15	7.28	7.41	7.54	7.67	7.80	7.93
1.2	8.06	8.20	8.35	8.50	8.65	8.80	8.95	9.10	9.25	9.40
1.3	9.55	9.70	9.90	10.1	10.2	10.4	10.5	10.7	10.8	11.0
1.4	11.2	11.4	11.6	11.7	11.9	12.1	12.3	12.4	12.6	12.8
1.5	13.0	13.2	13.3	13.5	13.7	13.9	14.1	14.3	14.5	14.7
1.6	14.9	15.1	15.3	15.5	15.7	15.9	16.2	16.4	16.6	16.8
1.7	17.0	17.2	17.4	17.6	17.8	18.1	18.3	18.5	18.7	19.0
1.8	19.2	19.4	19.7	19.9	20.2	20.4	20.6	20.9	21.2	21.4
1.9	21.7	21.9	22.1	22.4	22.7	23.0	23.2	23.4	23.7	24.0
2.0	24.3	24.5	24.8	25.0	25.3	25.6	25.8	26.1	26.4	26.7
2.1	27.0	27.3	27.6	27.9	28.2	28.5	28.8	29.1	29.4	29.7
2.2	30.0	30.3	30.6	30.9	31.2	31.5	31.9	32.2	32.5	32.8
2.3	33.1	33.5	33.8	34.1	34.5	34.8	35.1	35.4	35.8	36.1
2.4	36.5	36.8	37.1	37.4	37.8	38.2	38.5	38.8	39.1	39.5
2.5	39.9	40.3	40.6	41.0	41.4	41.7	42.1	42.4	42.8	43.2
2.6	43.6	43.9	44.3	44.7	45.1	45.5	45.8	46.2	46.6	47.1
2.7	47.5	47.9	48.2	48.6	49.0	49.4	49.8	50.2	50.7	51.1
2.8	51.6	52.0	52.4	52.8	53.3	53.7	54.1	54.5	54.9	55.4
2.9	55.9	56.3	56.7	57.2	57.6	58.1	58.6	59.1	59.5	59.9
3.0	60.3	60.8	61.3	61.8	62.3	62.8	63.2	63.7	64.1	64.6
3.1	65.1	65.6	66.1	66.6	67.1	67.5	68.0	68.5	69.0	69.5
3.2	70.0	70.5	71.0	71.5	72.0	72.5	73.0	73.5	74.0	74.5
3.3	75.0	75.5	76.0	76.5	77.0	77.6	78.2	78.7	79.3	79.9
3.4	80.5	80.9	81.5	82.0	82.6	83.1	83.6	84.2	84.8	85.3
3.5	85.9	86.5	87.1	87.7	88.3	88.9	89.5	90.1	90.7	91.3
3.6	91.9	92.5	93.1	93.7	94.3	94.9	95.5	96.1	96.7	97.4
3.7	98.0	98.6	99.2	99.8	100	101	102	102	103	104
3.8	104	105	106	106	107	107	108	109	109	110
3.9	111	111	112	113	113	114	115	115	116	116
4.0	117	----------	----------	----------	----------	----------	----------	----------	----------	----------

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[1] Rating derived from tests made at the National Bureau of Standards using flat floor.

[2] Trace.

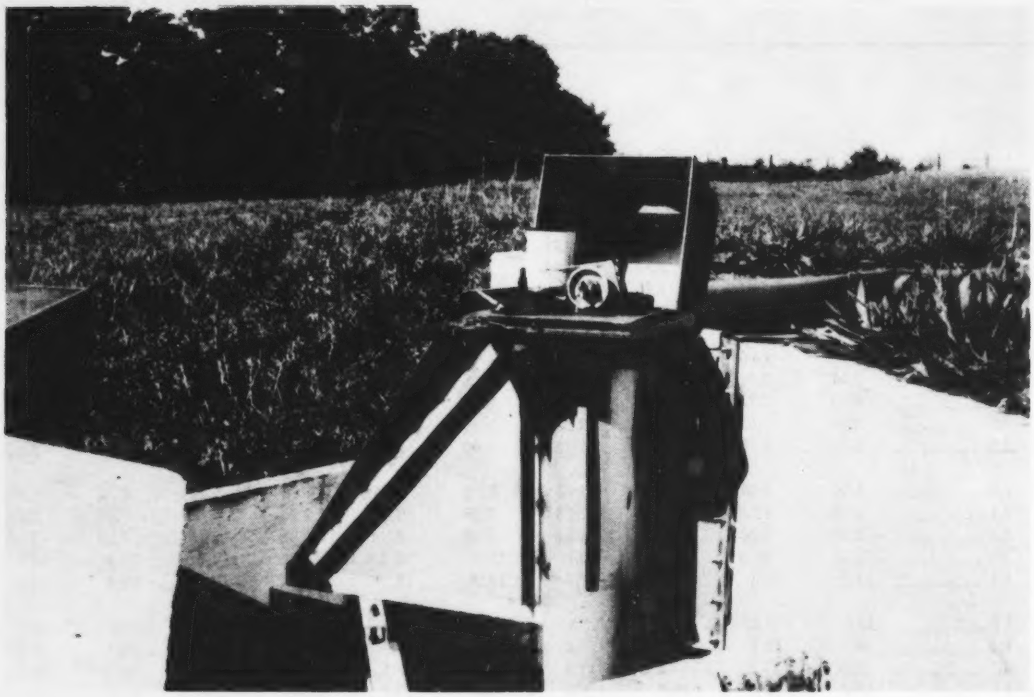

FIGURE 3.15. Stilling well attached to flume.

3.3.3 Selection of Automatic Sampler

To determine the amount of pesticide residue transported in runoff, samples must be taken in proportion to flow volume or elapsed time during the event. Pesticide concentration measurements and stage height measurements must be "paired" in time sequence to allow calculation of pesticide runoff quantities due to the dynamic nature of the runoff hydrograph. The collection of composite samples representing whole events are not adequate for runoff model development studies because they mask the dynamics of the event as illustrated in Figure 3.16. Composite samples will suffice if the only goals of the study are calibration of models requiring only composite information or evaluating total pesticide runoff quantities. The sampler must be set to ensure an adequate number of samples are collected at low flows (small runoff events) as well as obtaining a practical number of samples during high flow storm events. More samples are required at frequent intervals (e.g., 2 minutes) during the early stage of the hydrograph (discharge plotted over time) with less frequent sampling during the falling stage and the remainder of the event. If an evaluation of interflow and groundwater flow components is a major objective of the study, it would be advantageous to take more samples later in the storm hydrograph. Dynamic sampling techniques are particularly important because of the non-linear relationship between flow rate and sediment/pesticide transport.

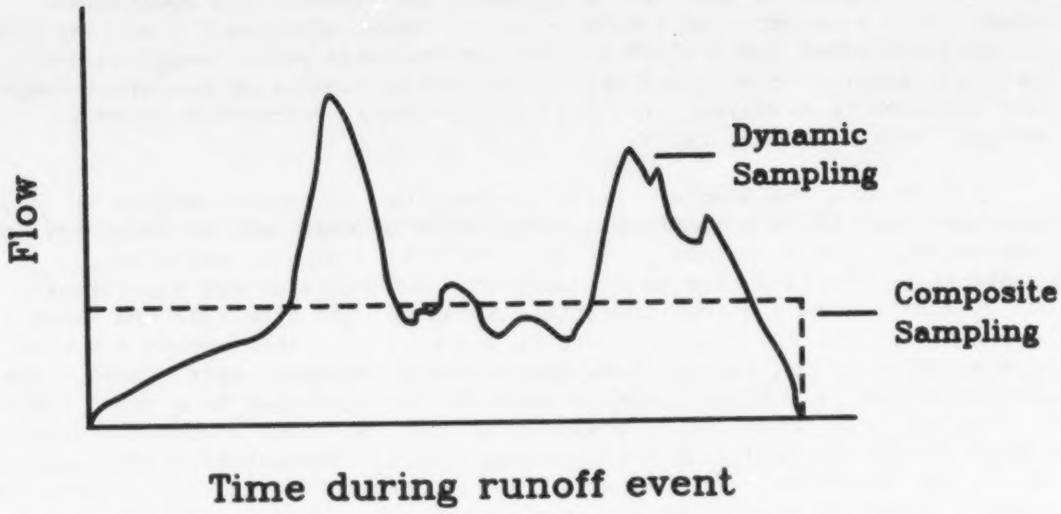

FIGURE 3.16. Illustration of composite sampling failure to adequately represent dynamic flow fluctuations within an event.

Several different runoff samplers have been used in past field runoff studies including the traversing-slot device (Smith et al., 1978), the pumping sampler (Johnson and Baker, 1982, 1984), and the coshocton wheel device (Ellis et al., 1977). More recently, automatic samplers (e.g., ISCO®) are being used by various governmental agencies for runoff and waste sampling studies (M. Koenig, U.S. EPA, personal communication, 1985). These samplers are flexible in that sample times can be preset for timed sampling during the event or proportional to flow by using an attached flow meter. The sampler can be activated by AC or DC current when rainfall starts by using an electronic conductance cell or by a mechanical linkage to the stilling well float. Samplers can be set to trigger at a small predetermined stage height to prevent initiation of sampling for rainfall events which do not produce runoff.

If the sampler intake has a suction line strainer, it should be removed to allow a representative sample of the sediment to be collected. In addition, the strainers are usually made of plastics that can potentially sorb pesticides.

The number of samples collected should be sufficient to represent the runoff event as discussed previously. The limitation on the number of samples is determined by the volume of sample required for analysis. Sample volumes of 1000 mL or greater are often used. To obtain samples of these volumes with an automatic sampler that has a capacity of 24-350 mL glass bottles requires programming the sampler to allow a sample to be collected in several bottles. This necessarily limits the number of samples collected per event. An additional sampler can be used to increase the number of samples that can be collected per event. The additional sample could also serve as a back up unit. Amber glass sample bottles with Teflon-lined caps® and Teflon® bottles are suitable runoff sampling containers. Plastic or Nalgene® are not desirable because of potential sorption problems (W.R. Payne, Jr., U.S. Environmental Protection Agency, personal communication, 1985).

Positioning the sampler intake in the flume to obtain samples is very important and can be accomplished in a number of ways, all of which involves compromises. One complication is that vertical sediment concentration gradients in the flume are to be expected. One satisfactory experimental set up that alters the sampling intake location with flow rate and which does not obstruct the flow is shown in Figure 3.17. This method was used by EPA Region IV (M. Koenig, U.S. EPA, personal communication, 1985). The sampler intake is suspended with a cable or rope attached to a metal float (a stilling well float can be adapted for this use) that allows the sample intake to rise or fall with the incoming runoff. The intake should extend one to two inches below the float. A metal weight is connected to keep the sampler intake in an upright position in the water column. In addition, the float and intake may need to be secured so that the device does not drift to the flume outlet with the flowing runoff. Modifications in the suggested design may be required to meet each user's need. In order to transport sands, the sampler should have a pumping rate of >2.5 ft^3/sec (75 cm/sec) transport velocity using a 1/4 in. ID or larger Teflon® sampling tube (U.S. EPA, 1979).

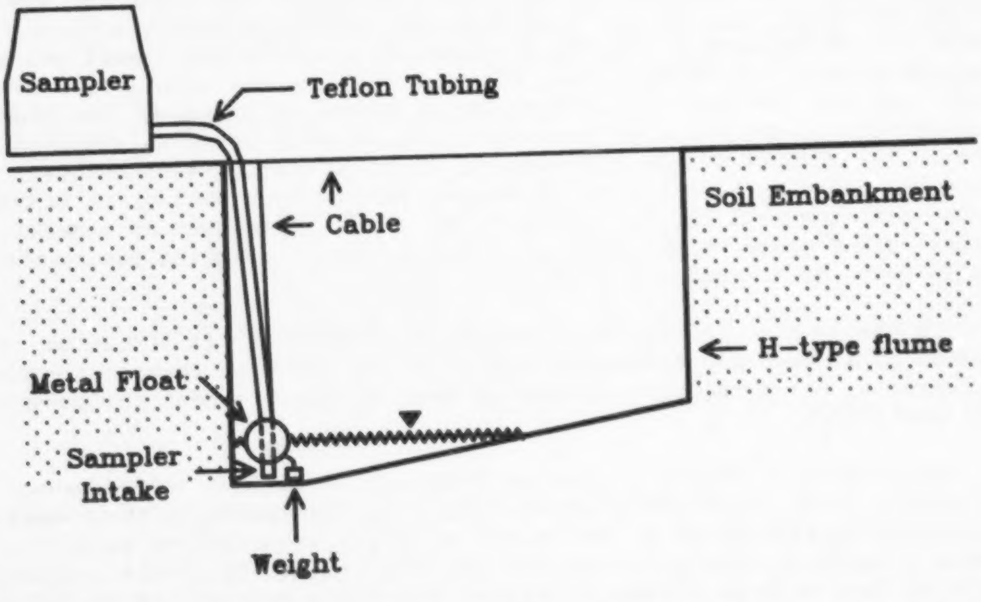

FIGURE 3.17. Example of positioning sampler intake in H-type flume with sloping floor approach.

3.4 METEOROLOGICAL STATION

Monitoring weather or meteorological parameters at the field site is an essential data requirement because these parameters influence runoff and persistence of pesticides. Runoff models require varying interval (e.g., hourly, daily etc.) records for the various meteorological parameters. The required data include precipitation (rain and snow), pan evaporation, solar radiation, air temperature, relative humidity, and wind. Each of these parameters will be discussed in a general way to provide the user of this manual with sufficient information and sources to establish a weather monitoring station at the field site. An excellent source of information is the USDA (1979). A typical weather monitoring station is shown in Figure 3.18.

3.4.1 Site Location Requirement

The weather station should be near the field in an open area isolated from buildings, trees, vegetation and other obstructions. It also should be located for easy access because daily observations are required. The door of the instrument shelter should open to the north, and a mesh wire fence is required to secure the station from animals. The use of concrete or gravel should be minimized because of possible temperature effects, and a bird perch higher than the sampling instruments should be provided.

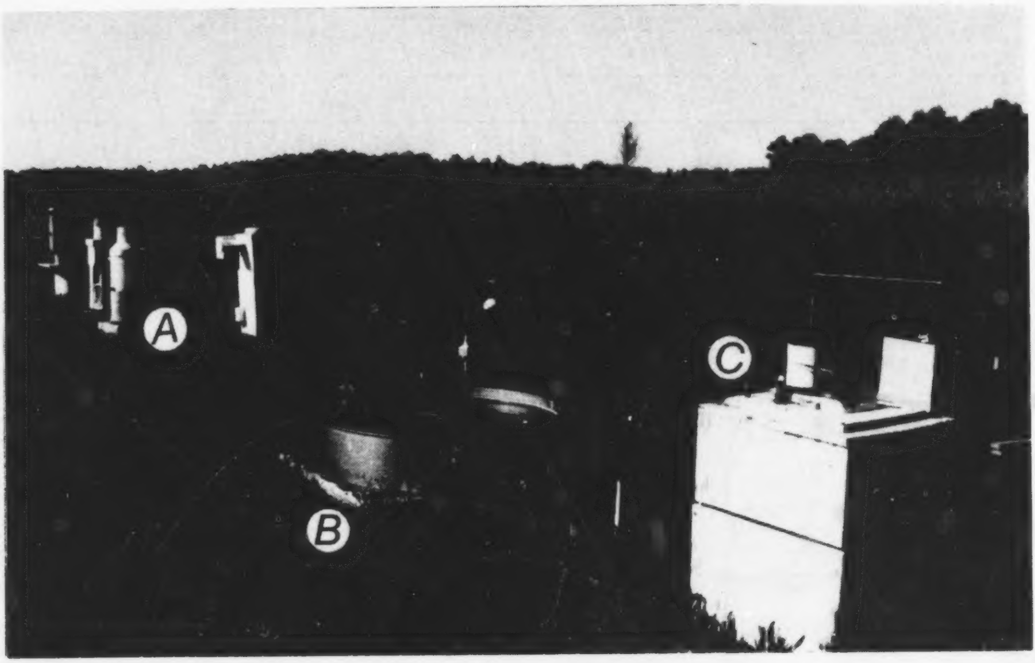

FIGURE 3.18. Example weather station, raingages and samplers (A), evaporation pan (B), strip recorder for measuring pan evaporation (C).

An important factor to consider in establishing a weather monitoring site is the use of recording instruments to provide continuous observations with permanent records and reduce time of daily observation measurements. One important part of collecting these data is to assign one project member (with an additional backup person) the responsibility of conducting routine maintenance of all equipment as well as keeping field notes, and compiling all data as they are being generated.

3.4.2 Precipitation

Precipitation includes both rainfall and snow accumulation depth measurements. Hourly or break point data will cover requirements for most runoff models. Precipitation gages in use include both recording and non-recording types. There are three types of recording precipitation gages: weighing, tipping bucket, and float types. The weighing type is the only one that will measure both rainfall and snow accumulation. An example rainfall chart from a recording gage is depicted in Figure 3.19. The digital precipitation gage (a weighing type) has an advantage over other types because the data are punched on paper tape (although the paper-chart type allows on-site inspection of data). This provides rapid data tabulation in a form suitable for computer analysis. For extensive details on calibration, potential errors, maintenance, data tabulation for various type precipitation gages see USDA (1979).

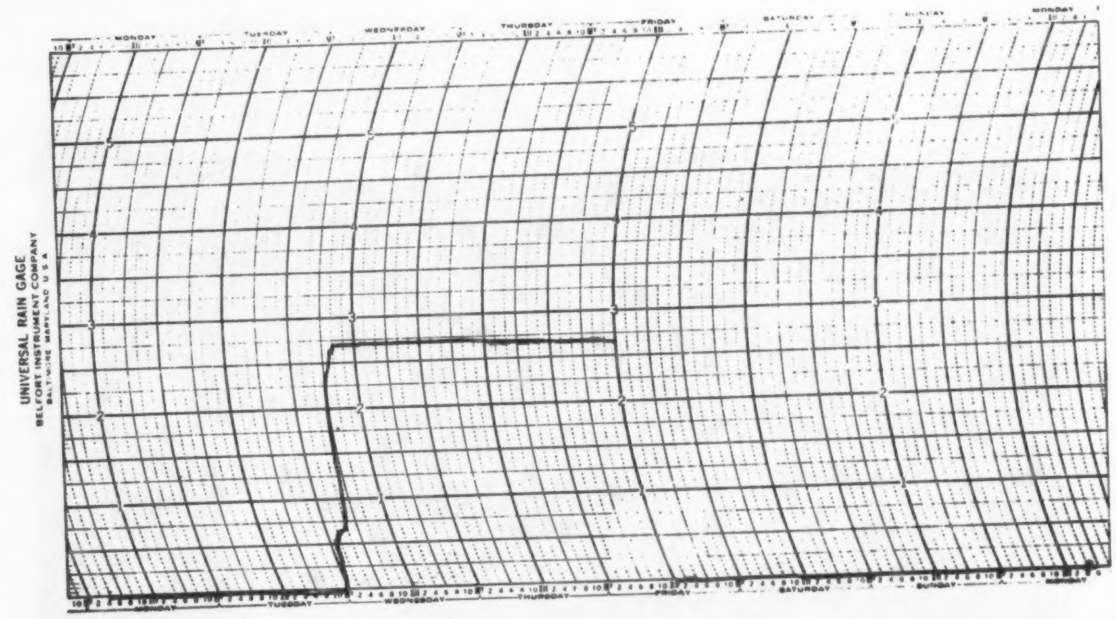

FIGURE 3.19. Rainfall chart from weighing-type recording gages.

The number of gages needed at a site depends on the size of the study area. For small areas (<10 acres), two raingages located at oposite ends or sides of the field are preferred because each will provide a backup to the other if failure occurs (i.e., clock stopped, pen or ink problems, etc.). In addition, it is helpful to locate an inexpensive, non-recording gage (measurement of total precipitation) at the site for measurement checks as shown in Figure 3.20. Discussion relative to the preparation of observed precipitation records for use in modeling is presented in Section 6.1.1.1-6.1.1.3.

Along with precipitation measurements, instruments are available for collecting samples of precipitation for determining the amount of pesticide residue being applied to the field from other sources, such as atmospheric fallout due to volatilization and drift of pesticides.

3.4.3 Evapotranspiration

Evaporation of water is measured from a standard National Weather Service 4-ft. (1.22M) diameter, Class A pan (Figure 3.20). Daily potential evapotranspiration (ET) data are required for most runoff models. One method for obtaining ET is to convert daily pan evaporation data by using a pan factor (dimensionless number) as shown in Figure 3.21. Several other methods are available that are used in various runoff models. Some methods require different climatic measurements including solar radiation, wind

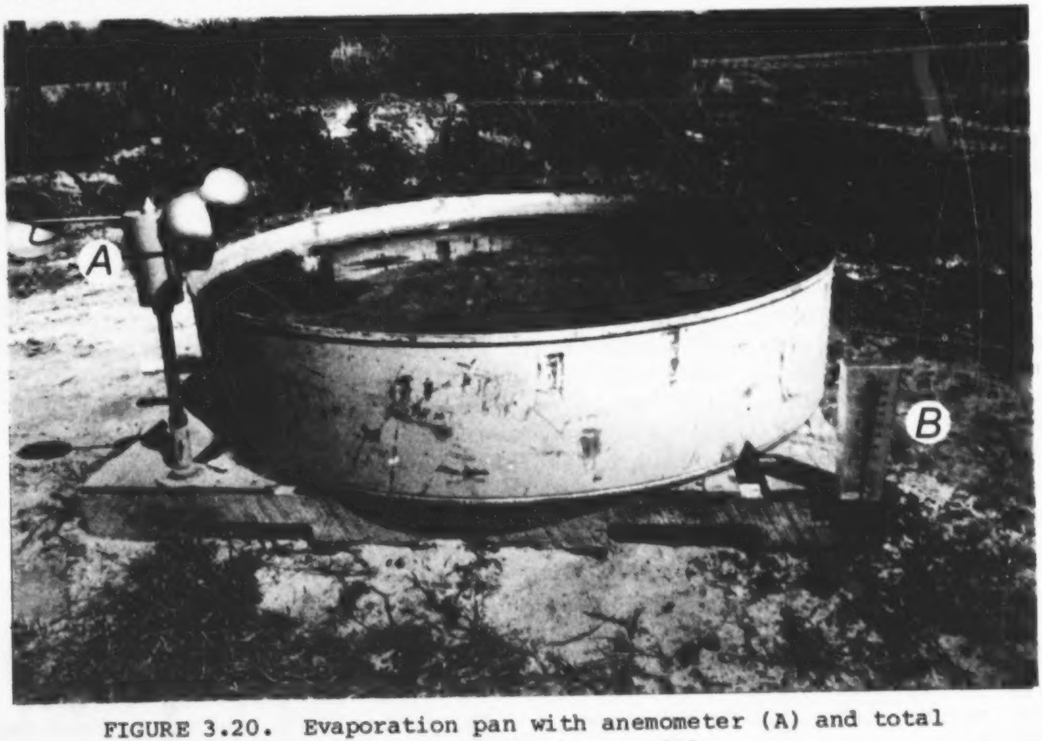

FIGURE 3.20. Evaporation pan with anemometer (A) and total precipitation check gage (B).

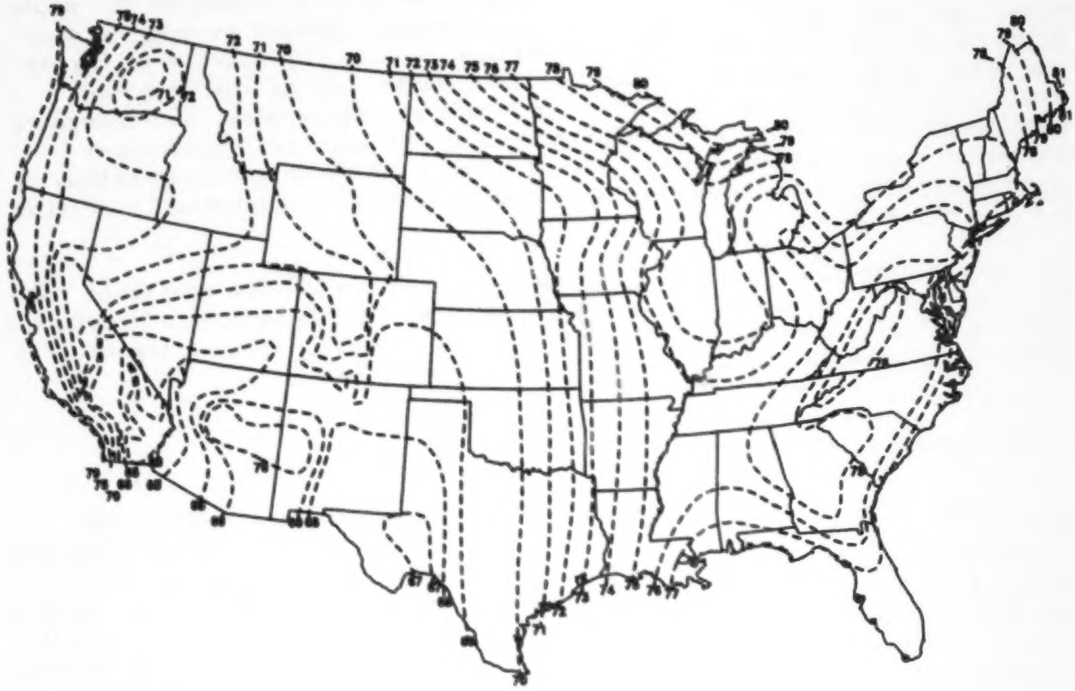

FIGURE 3.21. Pan evaporation correction factors (from U.S. Weather Bureau).

speed and temperature. The measurements obtained should correspond to the particular method for obtaining potential ET. In addition to pan evaporation measurements, total wind (miles/day) measurements are required because wind influences evaporation. Anemometers are available that measure total wind for each day (counter records tenth mile (161m) increments). This instrument requires the observer to visit the site daily to record the 24-hour wind movement. Daily observations are also required when using a standard hook gage to measure evaporation losses from the evaporation pan. An example record sheet for daily observations is provided in Figure 3.22. A continuous water level recorder system can be connected to the evaporation pan, as shown in Figure 3.18 (Ellis and Thomas, 1968). Additional information regarding these measurements are described in USDA (1979).

3.4.4 Solar Radiation

Radiation is the most important factor in the evapotranspiration process. Daily radiation measurements are required for some runoff models if snow accumulation is anticipated. Radiation is measured by use of pyranometers coupled to a recorder system with an integrator providing 24-hour values. For more information on solar radiation measurements, see USDA (1979).

Evaporation and Climatological Observations

______, 19__

Date	Time of Observation	Observer	Air Temperature, °F Instrument Shelter			Evaporation						
						Anemometer Dial (miles)	24 Hr. Movement (miles)	H_2O Temperature		Hook Gage (inches)	Tank Filled (inches)	Evaporation (inches)
			Maximum	Minimum	Current			Maximum	Minimum			
1												
2												
3												
4												
5												
6												
7												
8												
9												
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FIGURE 3.22. Example record sheet for daily meteorological observations.

3.4.5 Air Temperature and Relative Humidity

Daily maximum and minimum air temperatures are needed to determine mean daily air temperature for computing potential evapotranspiration and for modeling snowmelt. Instruments consist of maximum and minimum thermometers mounted inside a standard U.S. Weather Service instrument shelter. In addition, a recording hygrothermograph can be placed on the floor of the shelter house to provide a measure of air temperature and relative humidity as shown in Figure 3.23. Humidity of the air influences the rate of evaporation losses and is required for computing potential evapotranspiration. Daily observations on a specific time schedule are required.

3.4.6 Wind

A measure of wind (speed and direction) is a model requirement that influences evapotranspiration and volatilization of pesticide residue in surface soils as well as affecting snowmelt. Wind velocity is measured with anemometers that are positioned at standard heights. For general information on speeds and velocities over a field site, the anemometer should be at a height of 33 feet (10m). When windspeed data are being used in calculating potential evapotranspiration by the Van Bavel (1966) or Penman (1956) methods, the anemometer should be at a height of 6.6 feet (2m). The weather bureau method (Kohler et al., 1955) requires the anemometer to be positioned at the evaporation pan height (2 ft or 61.0 cm) as shown in Figure 3.20. Additional information is provided in USDA (1979).

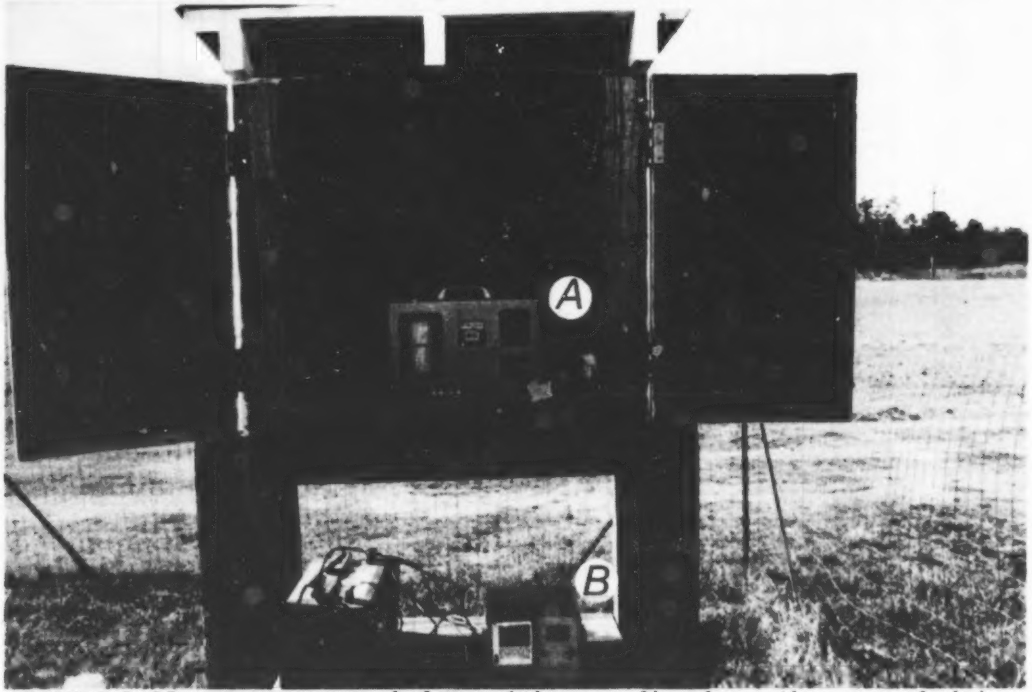


FIGURE 3.23. Instrument shelter with recording hygrothermograph (A) and anemometer recorder (B).

3.5 SOIL CHARACTERIZATION

The characterization of soil properties is an essential part of a field runoff study because these properties affect sampling design and runoff and erosion losses. It is preferred that soil core samples of each soil series be taken from the field site for analysis and characterization. If on-site expertise (qualified soil scientist) or laboratory facilities are not available, commercial organizations and cooperative extension service offices (soil test laboratories) are well qualified to assist with soil textural and chemical analyses. In addition, general soil characterization data are available from other sources:

- Soil survey data by county for each state. Available through county or USDA-Soil Conservation Service (SCS) state offices.

- Soil survey investigation reports (SSIR) for most states are available through SCS state offices. (The observed data are limited since only a small segment of a particular state is represented.)

- The USDA/SCS computerized and interactive soils information system data base is available for a fee through the U.S. Army Corp of Engineers, Construction Engineering Research Laboratory, Champaign, IL (Goran, 1983).

Specific soil characterization data that are essential include soil series identification, hydrologic soil group, soil texture, organic carbon content, bulk density, soil water content, soil pH, and temperature. These data are needed with depth in the soil profile (i.e., to a depth of 150 cm or lower extreme of the plant root zone).

3.5.1 Series

As discussed previously, soil survey reports that contain soil maps are available through USDA/SCS. From these maps the soil series can be identified for the selected site. Maps of this type, however, cover such a broad area that resolution at smaller scale (field) is not adequate. Therefore, the local USDA/SCS office should be contacted for assistance in identifying the soil series as well as describing the soil profile, as shown for a typical soil pedon description, Table 3.3. Once the soils are identified, a soil map of the field should be constructed with boundaries showing the distribution of soil types. This information will be useful in selecting sites by weighting the different series within the field for monitoring.

3.5.2 Hydrologic Group

Soils are classified into four hydrologic groups based on their infiltration rates (USDA, 1973):

- Group A. (Low runoff potential). Soils having high infiltration rates even when thoroughly wetted and consisting chiefly of deep, well to excessively drained sands or gravels. These soils have a high rate of water transmission.

- Group B. (Moderately low runoff potential). Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.

- Group C. (Moderately high runoff potential). Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine texture. These soils have a slow rate of water transmission.

- Group D. (High runoff potential). Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a clay pan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

Obviously, hydrologic soil group "A" would be less likely to produce runoff than soil group "D". Infiltration capacity of the soil should be given major consideration as it will affect the quantity of runoff produced from the area. A list of soil series and their associated hydrologic classification are found in Appendix D.

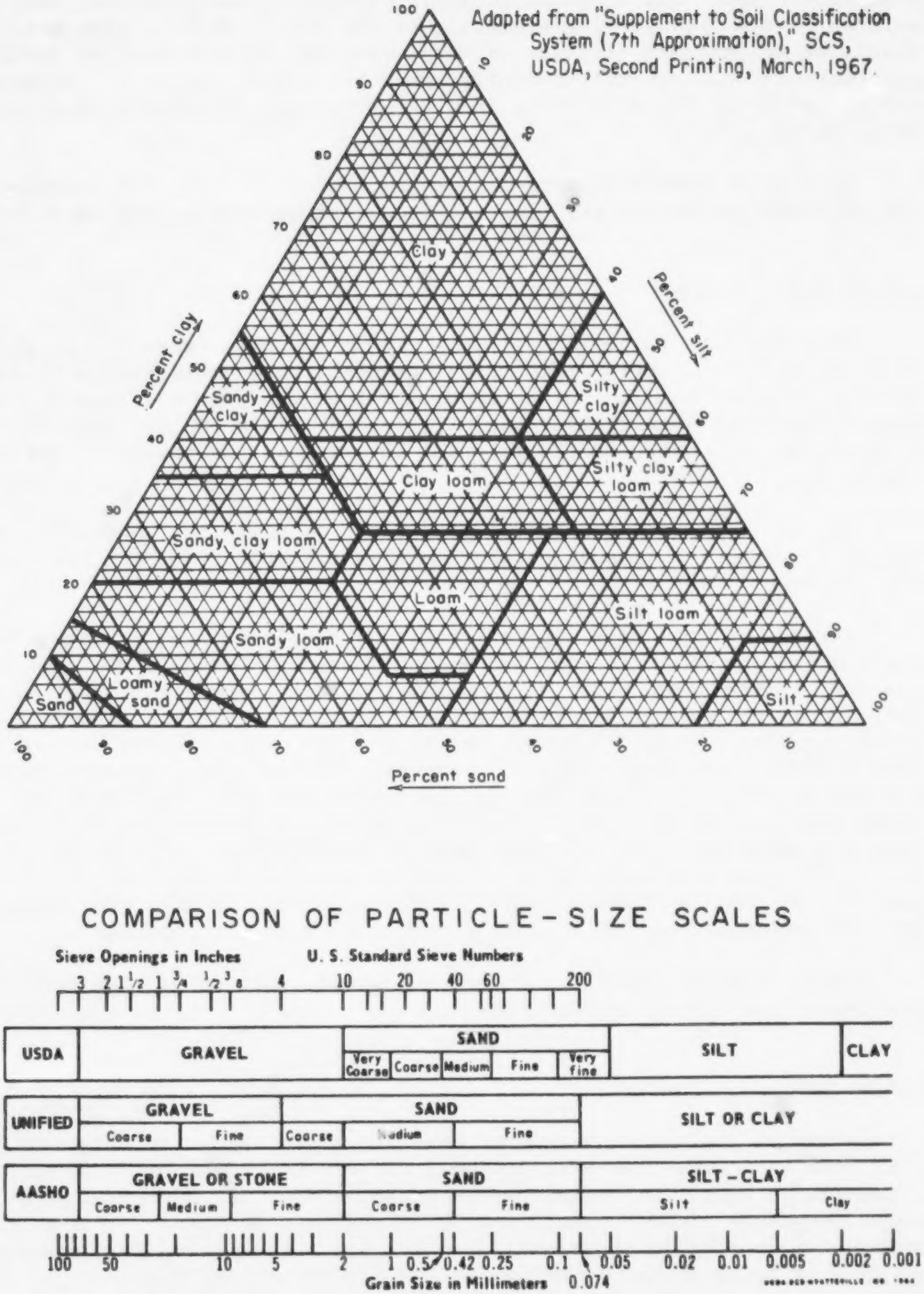
3.5.3 Texture

Soil texture deals with the distribution of various soil separates (i.e., sand, silt and clay). All soils can be grouped into 12 textural classes. The textural class is obtained by using the textural triangle as shown in Figure 3.24 in conjunction with the percent sand, silt and clay content. Soil texture influences erosion and sediment losses during the runoff process.

Methods to determine soil texture are presented by Day (1965) and Weber (1977).

3.5.4 Organic Carbon Content

The soil organic carbon is recognized as the most important soil property affecting sorption and transport of uncharged pesticides (Karickhoff, 1984). Carbon exists in soils in four forms as discussed by Weber (1977). These include: (1) carbonate minerals; (2) highly condensed organic carbon on charcoal, and coal; (3) little altered organic residues of plants, animals, and microorganisms; and (4) altered and rather resistant organic



Adapted from "Supplement to Soil Classification System (7th Approximation)," SCS, USDA, Second Printing, March, 1967.
100
90
80
70
60
50
40
30
20
10
Percent clay
Percent silt
Percent sand
Clay
Sandy clay
Silty clay
Clay loam
Silty clay loam
Sandy clay loam
Loam
Silt loam
Sandy loam
Loamy sand
Sand
Silt
COMPARISON OF PARTICLE-SIZE SCALES
Sieve Openings in Inches
U. S. Standard Sieve Numbers
3 2 1½ 1 ¾ ½ ⅜ 4
10 20 40 60 200
USDA
GRAVEL
SAND
Very Coarse
Coarse
Medium
Fine
Very fine
SILT
CLAY
UNIFIED
GRAVEL
Coarse
Fine
SAND
Coarse
Medium
Fine
SILT OR CLAY
AASHO
GRAVEL OR STONE
Coarse
Medium
Fine
SAND
Coarse
Fine
SILT - CLAY
Silt
Clay
100 50 10 5 2 1 0.5 0.42 0.25 0.1 0.05 0.02 0.01 0.005 0.002 0.001
0.074
Grain Size in Millimeters

FIGURE 3.24. Guide for textural classification (U.S. Department of the Interior, 1973).

residues--humus. The sorption of most pesticides can be quantatively related to the organic carbon content of the soil. Methods have been developed to estimate sorption of pesticides as characterized by partition coefficients, K_p. Partition coefficients are normalized to the organic carbon using the K_{oc} defined by ($K_{oc} = K_p$/fraction of organic carbon) (Karickhoff, 1981).

Methods to determine organic carbon content for soil and sediment are presented by Nelson and Sommers (1982), Plumb (1981), and Weber (1977).

3.5.5 Bulk Density

Bulk density is the mass of soil per unit volume expressed as grams per cubic centimeter. This parameter is essential when converting soil sample results that are analyzed on a dry soil weight basis to a volume or area basis. The bulk density of freshly tilled soil is much less than that of a soil that has undergone crusting and settling as the result of rainstorms (Smith et al., 1978).

The range of bulk density of fine textured soils is 1.0 to 1.3, whereas course-textured soils usually range between 1.3 and 1.8 g/cm^{-3} (Miller et al., 1966).

Various methods of sample collection for bulk density determination are discussed by Blake (1965) and Blake and Hartge (1985). The core method has been extensively used. This method requires the collection of an undisturbed soil core with known volume (metal cyclinder). Methods for obtaining samples include impact procedures using driving devices and steady load devices--hydraulic jacks and tractor-mounted hydraulic soil samplers. The choice of equipment depends on the soil condition. Care must be exercised to minimize compaction with steady load devices and shaking with impact driving devices. If water content measurements are desired for each soil core, then the core should be wrapped in aluminum foil to retain the sample near its field water content. For bulk density determinations, the core is oven-dried at 105°C until a constant weight is obtained.

If bulk density samples cannot be collected, estimation techniques are available (see Carsel et al., 1984).

3.5.6 pH

Hydrogen ion activity has an effect on the dissipation of pesticides, i.e., some are less stable at low soil pH values and some at high pH, depending on their functional groups (Nash, 1980). In addition, many polar compounds undergo speciation reactions as a function of pH, which substantially affects their sorptive behavior. The method for determining pH in soil is presented by McLean (1982) and Weber (1977).

3.5.7 Temperature

Soil temperature affects the persistence of pesticides. The temperature of surface soils in loosely tilled condition (at the time when herbicides are commonly applied) is much higher than air temperature. For instance, Smith et al. (1978), showed that for a cecil sandy loam, surface soil temperature measurements taken on planting day were 15°C higher than prevailing air temperature (Table 3.6). Throughout the 7-day rainless period, air temperature was generally about 25°C. After the first rainfall event, surface soil temperature decreased markedly. Surface soil temperature would be somewhat less under conservation tillage regimes.

A discussion of various ways to monitor temperature is presented by Taylor and Jackson (1965). Thermistors with readings obtained by using a wheatstone bridge provide a convenient way to obtain temperature profiles with depth. They can be installed in a single hole using a 2.5 cm slide hammer type insertion tool (Figure 3.25). This tool is of the type commonly used for installing tensiometers. Several thermistors can be assembled in a harness (as illustrated in Figure 3.26) to assure proper positioning

TABLE 3.6. SURFACE SOIL (2.5 cm) TEMPERATURE AND MOISTURE FROM TIME OF APPLICATION TO FIRST RUNOFF EVENT (Smith et al., 1978)

Days after[a] Planting	Soil Temperature (°C)	Soil Moisture[b] (%)
0	45.2	7.0
1	30.4	5.4
2	33.1	2.9
3	49.0	1.8
4	38.2	1.9
5	29.2	2.6
6	29.2	1.4
7	18.7	3.6

[a] Runoff occurred on day 7 after planting.

[b] Determined gravimetrically.

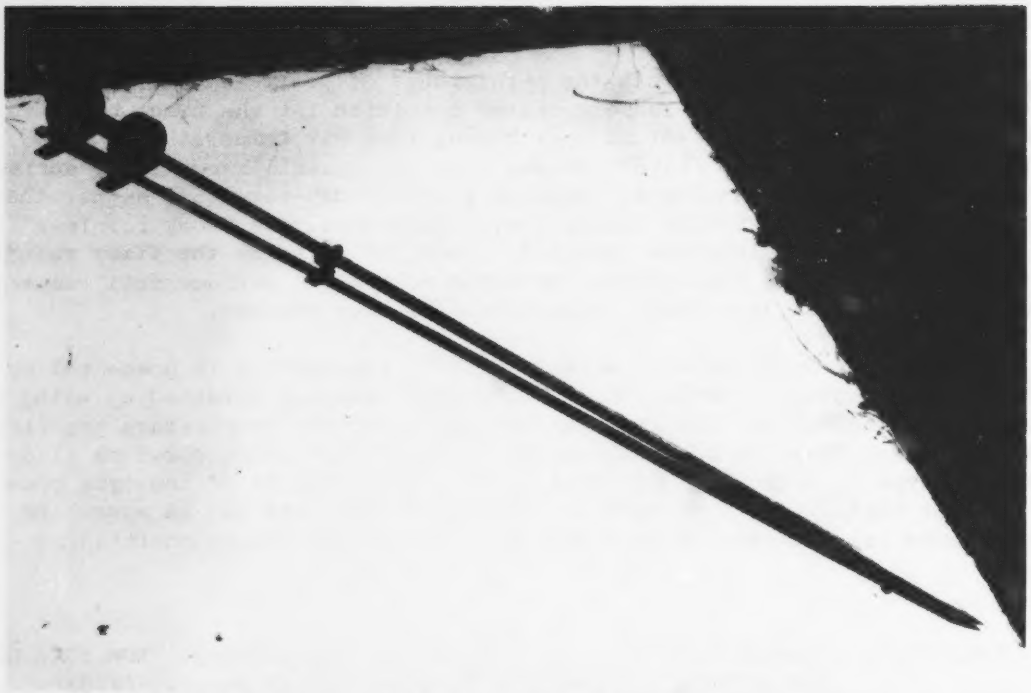


FIGURE 3.25. Tool for inserting temperature sensors.

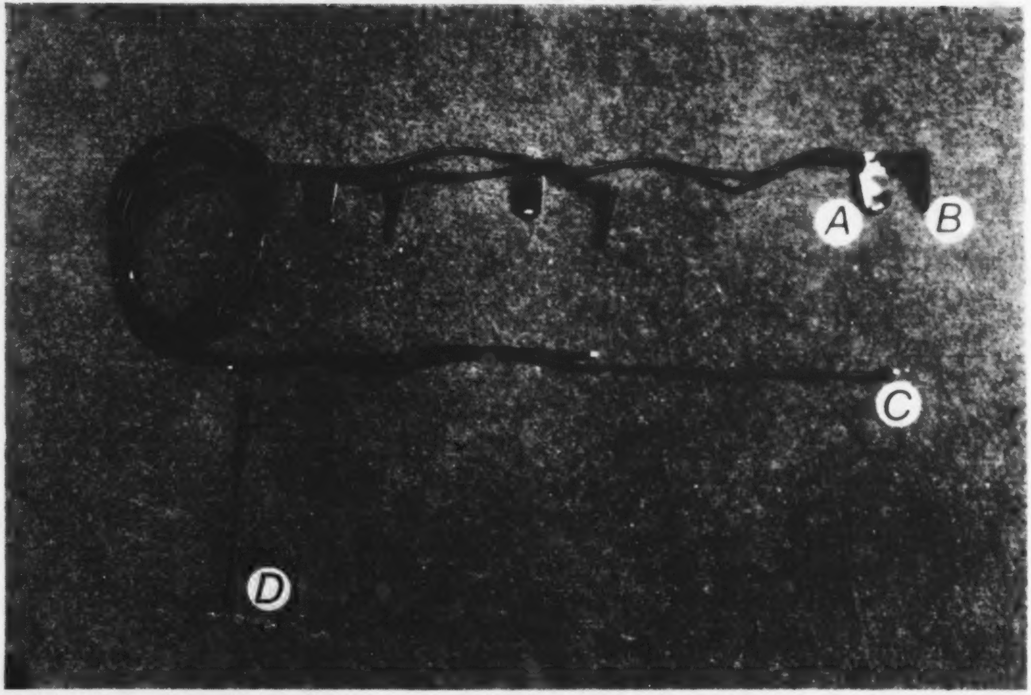


FIGURE 3.26. Thermistor harness consisting of label tag (A); jack (B), which is plugged into monitoring instrument; below ground sensor (C); and surface sensor (D).

while the insertion hole is backfilled with loose soil to provide good thermal contact. Aluminum label tags of the type used on gas chromatograph columns are convenient and durable devices for identifying sensor leads. It is important for each monitoring site to have sensors located at consistent depths. Soil temperature will vary with the diurnal cycle. Measurements should be made at short time intervals until this cycle is clearly apparent. Measurement schedules can then be optimized in accordance with model data needs.

3.5.8 Moisture Content

The moisture content of field soils has a direct influence on the dissolved-phase concentrations of a pesticide. Because of this, soil moisture content also has a substantial impact on the attentuation and transport processes. Soil moisture measurements are needed as a function of time and depth.

For field measurements, several methods are available for monitoring soil moisture that vary from collecting soil samples with depth (determined by gravimetric analysis) to indirect measurements by use of electrical resistance sensors (gypsum blocks, etc.), tensiometers, and radiological methods.

When the objective is to collect soil moisture data on a minimum number of samples and high precision is required, the gravimetric method is usually preferred. If large numbers of samples are anticipated, consideration should be given to possible field disturbances caused by the boreholes. The gravimetric method (Gardner, 1965) will require less time than other methods unless very time intensive measurements are required. If the objective is to collect daily moisture data for a large number of sites (soil variability known to be large) for a period of 2 to 3 years, then an indirect method would probably be more appropriate. Indirect methods require extensive calibration and installation efforts, but are efficient once operational. For multiple year studies, it is important to recognize that sensor installation within the plow zone may have to be disturbed to accommodate normal tillage operation. This fact should be acknowledged when considering trade off between gravimetric and indirect methods. Metal detectors provide an efficient means of locating permanent sensor leads that have been temporarily buried to accommodate tillage. Smith and Carsel (1985) used discarded automobile brake drums to protect and house buried sensor leads. The brake drum provides a large target for the metal detector and yields high sensitivity in relocating buried sensor leads.

Some runoff models require soil moisture release characteristic curve (matric potential versus water content). These data range from saturated hydraulic conductivity (0 bar) to -0.33 bar (field capacity) and -0.15 bar (wilting point) potentials. For a discussion regarding these measurements, see Peters (1965). Techniques for obtaining undisturbed soil core samples for these measurements are discussed in Section 3.5.5. Both field capacity and wilting point determinations can be made in the laboratory using pressure chambers. Bulk density determinations discussed in Section 3.5.5 are required for these measurements to facilitate conversion of soil moisture content from oven-dry basis to a volume basis as required in most models. Additional information regarding the preparation of data for model use is presented in Section 6.1.1.4.

3.5.9 Infiltration Rate

Mean soil infiltration rate is a model requirement because it affects water runoff quantity and quality (see Section 2). The mean soil infiltration rate should be obtained at the site. A discussion of methods to measure infiltration is presented by Bertrand (1965), Bower (1985), and Peterson and Bubenzer (1985).

3.6 A WORD OF CAUTION REGARDING ON-LINE FIELD DATA SYSTEMS

On-line computerized data collection systems using a variety of electronic sensors offer an attractive alternative to manual sampling methods where intensive sampling schedules are planned. Soil moisture, soil temperature, air temperature, relative humidity, solar radiation, wind speed and direction, and rainfall are examples of measurements that are be made by this means. This apparently very labor efficient approach is, however, subject to a number of very real limitations posed by the field environment. Wind, rain, dust, high and low temperature extremes, and variable humidity conditions all contribute to the difficulty of providing workable environments for field installed computers. Stable line and backup power sources must be provided. Buried sensor wiring harnesses can involve miles of shielded wire and require major plot excavation during installation. Various interfacing electronics hardware and software are required for connection of sensors to the computer by means which provide automatic sampling and data storage. These seemingly surmountable requirements combine to yield complicated systems that are difficult to maintain in fully operational condition. From past experience in the operation of a automated field data acquisition system (Smith et al., 1975), the following factors merit consideration prior to the establishment of such a system.

a) Lightning--Experience has shown that lightning is a major threat to field electronic installations. Power poles located in open fields, above ground sensor posts (i.e., wind speed instruments) and long lengths of buried sensor wires provide good targets for lightning. Even somewhat distant strikes can cause stray currents to be transported through sensor wiring harnesses to the central computer. The result is almost always serious damage to the sensors, interfaces or the computer. This is particularly important for field runoff studies in that lightning strikes almost always coincide with key rainfall events.

    Lightning arrestors or grounding systems can be installed to minimize these problems. Figure 3.27 shows a field with an established grounding system.

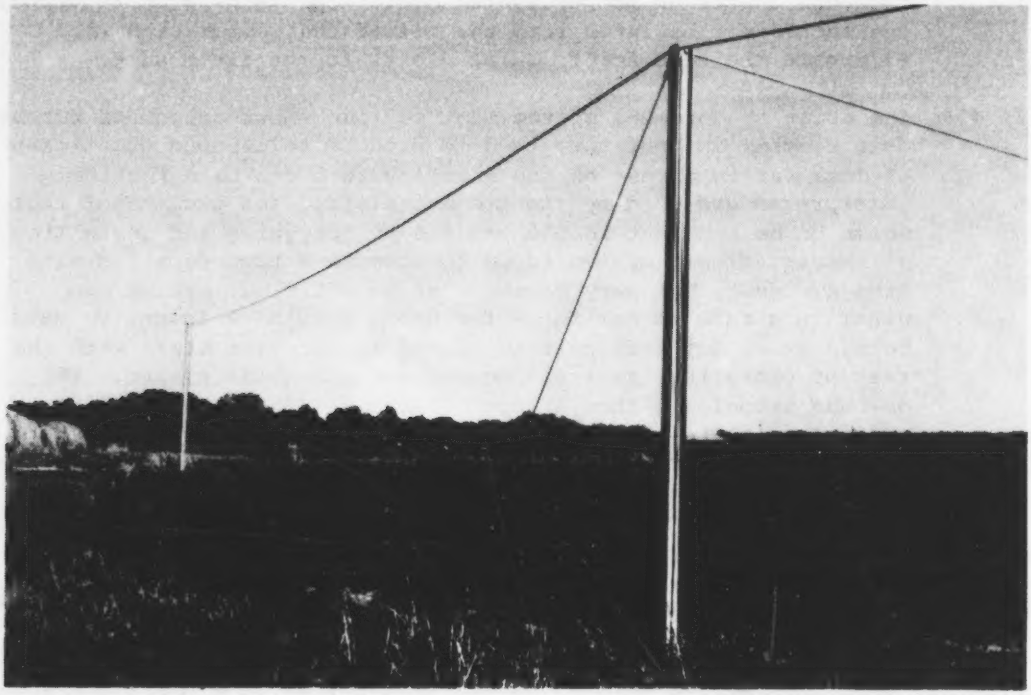


FIGURE 3.27. Example of field grounding system.

b) Power outage--Power outages, like lightning activity, are often keyed to storm events. A dependable backup power unit should be considered along with failsafe data storage and automatic restart computer facilities.

c) Vandalism, thieves, and pests--Unmanned, remotely located field installations offer attractive targets for vandals, thieves, stray livestock, rodents and birds. Good quality fences help to control livestock and pests and offer some deterrent to thieves. Nevertheless, some problems are to be expected from these sources and should be considered in the design of field installation.

d) Equipment failure--Field systems made up of large numbers of sensors, complex interfaces and supporting equipment are often subjected to inordinate downtime. Component failures are more frequent in the field due to lightning, power line surges, weather extremes and unauthorized tampering. This situation is compounded by the fact that failure of the most simple component can often damage other parts of the system or take the whole system down. The probability that all systems will be fully operational during any given series of storm events is not high.

e) Maintenance--Because of problems noted in items a through d, maintenance of a field based data acquisition system often becomes a very labor intensive exercise. Daily service and thorough checks on proper system operation are usually required. One should not be lured into the belief that automation will eliminate the need for frequent visits to the field site.

f) The human factor--One of the most serious shortcomings of automated data systems is that they tend to produce voluminous quantities of data far in excess of the quantity that can be effectively interpreted and used by the project staff. The excitement that seems to be inherent in the process of designing and installing an automated data system tends to promote a preoccupation with "the system." The very presence of an efficient system can generate a rash of new ideas for using even more intensive data sets. It is not difficult to occupy the project staff with the task of operating, maintaining and expanding the system. The obvious pitfall is that little effort is left available for critically reviewing and interpreting any of the data. It is important that project objectives and real data requirements are not lost to the excitement of building the data system.

3.7 SAMPLING NETWORK DESIGN

Sampling network design involves selection of the sampling sites for monitoring various parameters in space and time following application and after individual runoff events. To facilitate sampling for pesticide residues, the field should be divided into sampling areas. Figure 3.28 illustrates a typical sampling grid overlaying a soil series map. By overlaying

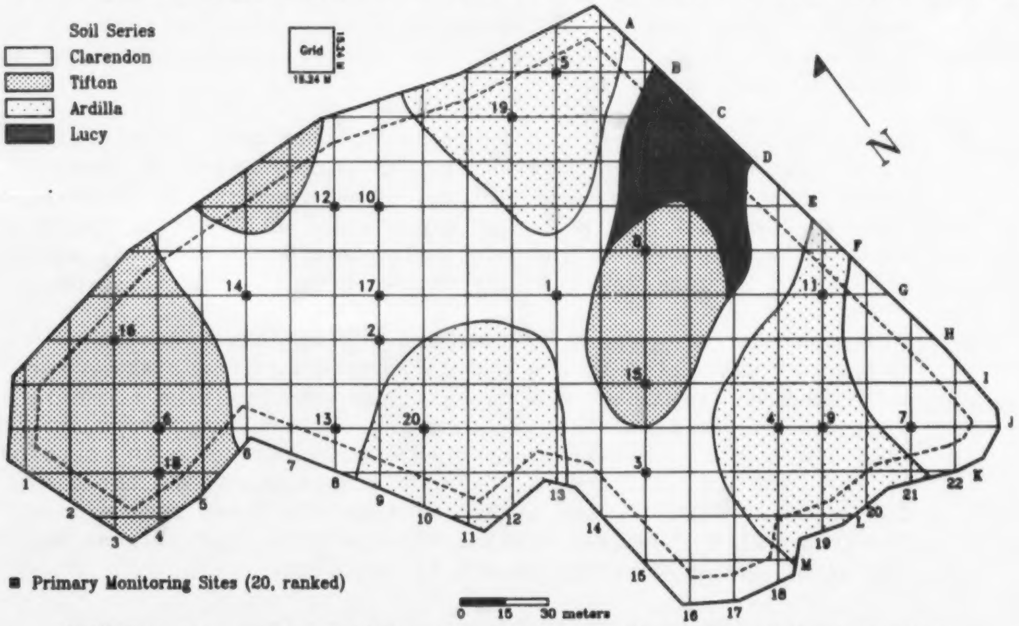


FIGURE 3.28. Illustration of a field design for characterizing pesticide degradation and transport.

a grid on the field unit, random sampling areas can be chosen at the grid intersections. This double overlay method distinguishes sampling area based on soil physical characteristics that may be important in influencing runoff. It also provides for an overall estimate of the entire area. Care should be taken to avoid degeneracy in sample labeling methods.

For grid sampling, grid line separations (resolution of grid) must be selected (e.g., 15.3 M) to provide a sampling area where independence is obtained. Independence is important because it will help to maximize the information available from the sample when optimum spatial independence is obtained. A sample size of 30 is regarded as reasonably large and depends somewhat on sample variability and on the degree of precision that is desired. A sample size of ten is regarded as the minimum number of sampling sites, Bresler and Green (1982). Without some estimate of variability, the required sample size cannot be projected with any real confidence. In preliminary sampling to estimate variability, however, relatively small sample sizes are reasonable. Obviously, more sites (n = 10 to 30) within a given field will provide additional information on the variance for estimating the true sample mean as well as addressing spatial variability impacts on runoff losses.

The number of samples to be collected and processed for residue analysis must be considered initially as a factor in the overall experimental design. Various type samples may be collected throughout the crop growing season that include: filter disc (monitoring application rates), soil core (application rate and residue analysis with depth and time), plant tissues (application distribution with foliar-applied insecticide), and runoff collections (both water and sediment).

3.7.1 Estimating Means and Totals

Prior to a discussion of sample collection, it is useful to review general statistical sampling principles for use in estimating means and totals for a given field.

The estimation of a total amount of compound that has been applied to a site can be considered in the context of estimating the mean value per unit area in the site and then multiplying by a numerical constant that yields the field total. Whenever sample data are obtained in the form of a simple random sample, it is straightforward to obtain numerical estimates of the population mean, the standard error of the estimate, and confidence intervals. For example, the sample mean is an estimate of the population mean; standard error of this estimate of the population mean is the sample standard deviation divided by the square root of the sample size; confidence intervals are based upon these two estimates.

Some standard formulas for calculation follow.

Population mean estimate = Sample mean

= SUM (observed value) / n

where n = number of values in the sample

Sample variance

= SUM ((observed value - sample mean)^2) / (n-1)

Standard error of the estimate of the mean

= SQRT ((sample variance) / n)

Confidence interval for the population mean:

(sample mean) ± t(n-2,alpha/2) X (std error of mean)

alpha (i.e., level of risk) = 0.05

Estimate of the population total

= N X (sample mean)

where N = total number of "sample units" in the population

Confidence interval for the population total:

N X (sample mean) ± N X t(n-2,alpha/2) X (std error of mean)

To estimate a population total, one must know the number (N) of "sample units" that comprise the population. For example, if filter discs are being used to estimate a mean quantity per disc, then in order to calculate how much is on the whole field, the area of the field must be considered with regard to the area of the discs. That is, N = (area of the field site)/(area of a filter disc). To calculate the total on the field, the standard error of this estimate, and confidence intervals, one need only multiply the respective estimates for the mean by the constant N.

Ideally, the samples should be collected at random. This means that all "candidate samples" have an equal chance of being selected at sampling time. In the present case, precautions should be taken to ensure that samples are taken far enough apart spatially so that the samples are not, in effect, measuring the same location. Selection of sampling points can be done from a grid overlay of the sampling area so that the intersection points denote the set of possible sample locations. The grid size usually should be chosen so that it is as fine as is practically possible, but not so fine as to permit two adjacent intersection points to be considered dependent. The set of all intersection points comprise the set of "candidate" sample points. In practice these can be numbered in any manner, and then a random selection of these can be made prior to collection time by using a table of random digits (see Appendix B).

3.7.2 Subdivision of the Study Area

A large field site can often be subdivided into a few smaller areas on the basis of easily observed criteria such as soil series, gradient, or elevation. Such a division may or may not serve to enhance the efficiency of statistical sampling plans. A division of this sort is often called a "stratification" of the sampling area. Generally, it is desirable to stratify an area if the stratification serves to produce subdivisions with significantly reduced variability compared to the whole site, relative to the variable that is to be measured.

An area that is properly and effectively subdivided can yield a more precise estimate of the field total than could be obtained with simple random sampling using the same number of samples. Such sampling techniques fall under the general heading of "stratified sampling." Basically, to do stratified sampling, one only needs to stratify the population and then randomly sample each subpopulation. The estimate of the population mean is, mathematically, just a weighted mean of the individual stratum means.

A question that arises almost immediately is in regard to the number of samples that should be used within each stratum. This generally is posed in the context of there being a fixed number of samples that are to be collected and "allocated" to the strata. Two common techniques are proportional allocation and optimal allocation. With proportional allocation, sample sizes are assigned in proportion to the sizes of the strata. With optimal allocation, the sample sizes are chosen so as to minimize the standard error of the estimate of the population mean. If a population is stratified, a general rule that should be followed is: Take a larger sample in a stratum if (a) the stratum is larger or (b) the stratum is more variable.

3.7.3 Systematic Sampling

Often there are situations that cannot be approached practically under a random sampling plan. That is, the requirement to select samples at random may place unacceptable hardships on the execution of the experiment. Random sampling is desirable for two main reasons. First, estimates of means and variances that are calculated are statistically rigorous. Second, by randomizing, objectivity is more suitably guaranteed. Still, the practical aspects of a situation may prevent competely random sampling. There is always a possibility, especially for small samples, that a random sample will not be a proper representation of the site being monitored. For larger samples, this is not a frequent occurrence. A systematic sample frequently will ensure that a representative sample is obtained. This is accomplished by selecting sample points in some uniform fashion over the whole field. This causes each small area of the field to be represented in the whole sample. The main objective in any sampling scheme is to obtain a sample that is representative of the underlying population and to do so in a manner that is statistically acceptable for the ensuing estimation of population parameters.

An example may be given for a situation in which it is desired to monitor the application rate of a spray-applied pesticide (see Figure 3.29). In the example, 100 equally spaced locations along the path of the tractor were chosen. Filter discs might be used to intercept a sample of the compound as it comes from a spray rig with multiple nozzles. Ideally, the location of the filter discs would be randomized over the field site, but it might not be possible to properly locate, pick up, and label the filter discs while the spraying operation is proceeding. An alternative would be to systematically place discs in front of the spray rig, collecting them in sequence as the compound is sprayed onto them. This makes the practical aspects more manageable and also ensures that the field will be adequately covered, giving a representative sample.

For a systematic sample, a population mean is estimated by the sample mean.

3.7.4 Determination of Sample Size

The question of sample size can be addressed rather easily provided certain preliminary information is available. The term "sample size" refers to the number of individual, independent measurements made on a particular variable of interest. A given sample size may be appropriate for some cases but not for others. It is important to realize that the size of a sample required in a given instance depends upon:

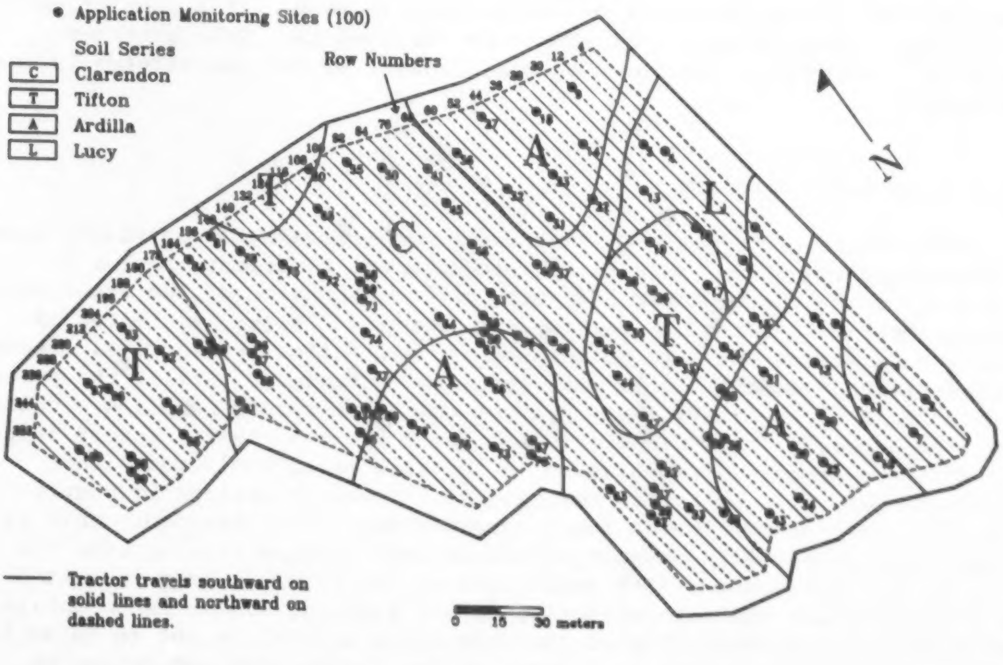

● Application Monitoring Sites (100)
Soil Series
C Clarendon
T Tifton
A Ardilla
L Lucy
Row Numbers
N
T
C
A
L
Tractor travels southward on solid lines and northward on dashed lines.
0 15 30 meters

FIGURE 3.29. Illustration of pesticide applications monitoring design using filter discs.

- inherent variability of the material being sampled, relative to the variable being measured;
- degree of accuracy required by the investigator;
- level of confidence that is needed in the estimate; and
- resources available to the study.

A sample size can be chosen large enough to ensure, with a certain level of confidence, that the estimate will fall within a specified distance of the true value. One cannot be absolutely certain that the estimate will be within that distance without sampling the entire population, which is usually impossible or impractical. There is always the possibility that the sample will be particularly bad, causing the estimate to lie further from the true mean than is desired. This will occur, on average, only as frequently as is permitted by the level of confidence required, however. For example, a decision to construct a 95% confidence interval admits a 5% chance that the true mean will not be contained in the interval yet to be determined. This risk (5%) is referred to as the error rate or alpha level. The nature of the inherent variability of the material being sampled cannot be changed, but by taking a large enough sample, the width of a confidence interval can be narrowed to any desired size. The greater the variability, the larger the required sample. Also, the higher the confidence needed in the estimate or the better the accuracy required, the higher the sample size. The degree of accuracy required normally will depend upon external considerations, as well as the level of confidence needed.

The general formula for sample size required is:

$$n \geq (ts/d)^2$$

Here, t is a percentile of the Student's t distribution, based on the sample size and the level of confidence; s is an estimate of the population standard deviation; and d is the largest acceptable difference between the estimate and the true mean value. The notation s relates to the inherent variability and must be estimated prior to the main sampling procedure; t is dependent on the investigator's specification of "alpha," i.e., his acceptable risk; and d is dependent on the investigator's accuracy requirement.

Example: Projecting the sample size for a filter-disc sampling experiment to determine application rate

Target application rate = 3.36 kg ha^{-1}

Accuracy desired (i.e., acceptable deviation from true value)
= + or - 20% of the mean

alpha (i.e., level of risk) = 0.05

Measure of variability (prior estimate):

coefficient of variation = 30%

Disc area = 269 cm^2/disc = 0.0269 M^2/disc

Expected mean per disk:

$3.36 \text{ kg ha}^{-1} \text{ X } 1 \text{ ha}/10^{-4} \text{ m}^{-2} \text{ X } 0.0269 \text{ m}^2/\text{disc} = 9.04 \times 10^{-6} \text{ kg/disc}$

Largest acceptable difference between true value and estimate:

$d = \text{accuracy} * \text{expected mean} = 0.20 * 9.04 \times 10^{-6} = 1.81 \times 10^{-6}$

Prior estimate of the population standard deviation:

$s = \text{c.v.} * \text{expected mean} = 0.30 * 9.04 \times 10^{-6} = 2.71 \times 10^{-6}$

A student's t-distribution table (see Appendix C) can be used to determine a value, dependent upon n and alpha, that satisfies the inequality:

$n \geq (t \text{ X } s / d)^2$

where t is the tabulated value (see Appendix C) corresponding to column heading 0.975, and n-2 degrees of freedom.

Here, the value n = 12 is satisfactory because using t (10, .975) = 2.228, we obtain 11.13 as the value on the right hand side of the inequality. This is the smallest value of n where inequality holds true. If accuracy were required to within 10% of the mean rather than 20%, n would be 36.

In certain cases, s and d will be known in numerical terms only, rather than in terms of the c.v. and the population mean, as above. Either way, this expression can be used in a trial-and-error sense to find a value for n that just works. It is in this manner that a sample size is determined. In the above, all that is needed is a suitable estimate for s and one for d. Values for s and d could be determined by a preliminary sample, as circumstances permit.

3.8 AGRICULTURAL PRACTICES

Agricultural practices affect the characteristics of the field site that have an impact on runoff and sediment transport. Conventional agricultural practices for a typical cropping year might include various activities, including:

- Spring till-disk, chisel plow, or moldboard plow
- Apply fertilizer - broadcast

- Disk incorporate fertilizer
- Plant and apply pre-emergence and post-emergence pesticide for weed control
- Cultivate for weed control four to six weeks after planting and one to two additional times prior to harvest (cultivation may not be required if proper herbicides are applied at planting)
- Apply foliar application of insecticide for insect control (for example, foliar applications to cotton begin when squares form and continue at weekly intervals thereafter)
- Apply defoliant as required
- Harvest crop and determine yield
- Use rotary mower to chop stalks
- Fall plow

Agricultural practices are, however, constantly changing to increase the production of food commodities for both domestic and world needs. The development and implementation of conservation tillage is being promoted as a means of reducing soil loss (sometimes runoff) and of providing savings in energy and labor (Carsel et al., 1985). Conservation tillage systems leave a protective crop residue on the soil that promotes greater infiltration. A recent model comparison study of no-till and disk harrowing using three representative pesticides on agricultural fields located in Georgia, Iowa, and New York indicated no-till reduced the potential for pesticide runoff and erosion losses. Pesticide leaching potential was increased, however, for two of the three sites (Carsel et al., 1985). Since conservation tillage practices are now in common use, studies to evaluate the impact of conservation tillage on pesticide runoff, leaching and water quality should be conducted. Conventional tillage is, however, still the predominant practice used in most regions of the United States. Donigian et al. (1985) reported the following percentages for conventional tillage in various regions:

Southeast	52%
Delta States	82%
Cornbelt	62%
Northern Plains	67%
Southern Plains	82%

Generally, conventional tillage will produce greater runoff, erosion, and pesticide losses in runoff. With respect to environmental assessments, this would result in a worst-case (convervative) estimate (Donigian et al., 1985). Tillage practices used in field runoff studies should reflect the most common practices for a given pesticide use area.

3.8.1 Crop Fertilization

Major fertilizer nutrients (N, P, K, lime) are typically applied by several methods. These include:

- broadcast before primary tillage
- top or side dress after crop is established
- foliar application of micro nutrients (S, Mn, Mo, Zn, etc.)

The actual combination of practices selected is determined by the crop, geographic location, weather conditions, and other local factors.

It is good practice to utilize services offered by commercial and state soil testing laboratories in determining fertilizer application rates. Many laboratories offer full recommendation services based on detailed knowledge of local areas. These laboratories will require collection of representative soil samples. Details on sample collection, containers, and labeling can be obtained from the testing laboratory personnel, or local extension service (agents), or fertilizer suppliers.

3.9 PESTICIDE APPLICATION

Pesticides are commercially available in liquid, wettable powder, and granular formulations. The formulation and method of application have an impact on runoff. Liquid and wettable powders are usually sprayed directly on the soil or plant surfaces. Granular pesticides are applied only to the soil, and in most cases, incorporated by tillage. Wettable powders that are applied to the soil surface consistently show the highest long-term losses of any general class of herbicides (Wauchope, 1977). Some surface-applied pesticides are rapidly lost from the soil surface due to volatilization or photochemical degradation processes. These compounds must be incorporated into the soil at the time of application as recommended by the manufacturers. Various methods of incorporation are typically used. These include disk harrowing, rotary tilling and use of a variety of mechanical incorporation implements designed for this purpose.

Typical application devices include conventional ground equipment, aerial sprayers, and chemigation equipment. Other less used methods are wick applicators, controlled droplet applicators, and electrostatic equipment. Typical ground equipment usually involves a trailer- or tractor-mounted tank, pump and boom system as illustrated in Figure 3.30. Aerial application systems have similar equipment built into specialized crop dusting planes and helicopters. Chemigation systems involve blending chemicals with irrigation waters, which facilitates chemical application as a part of the

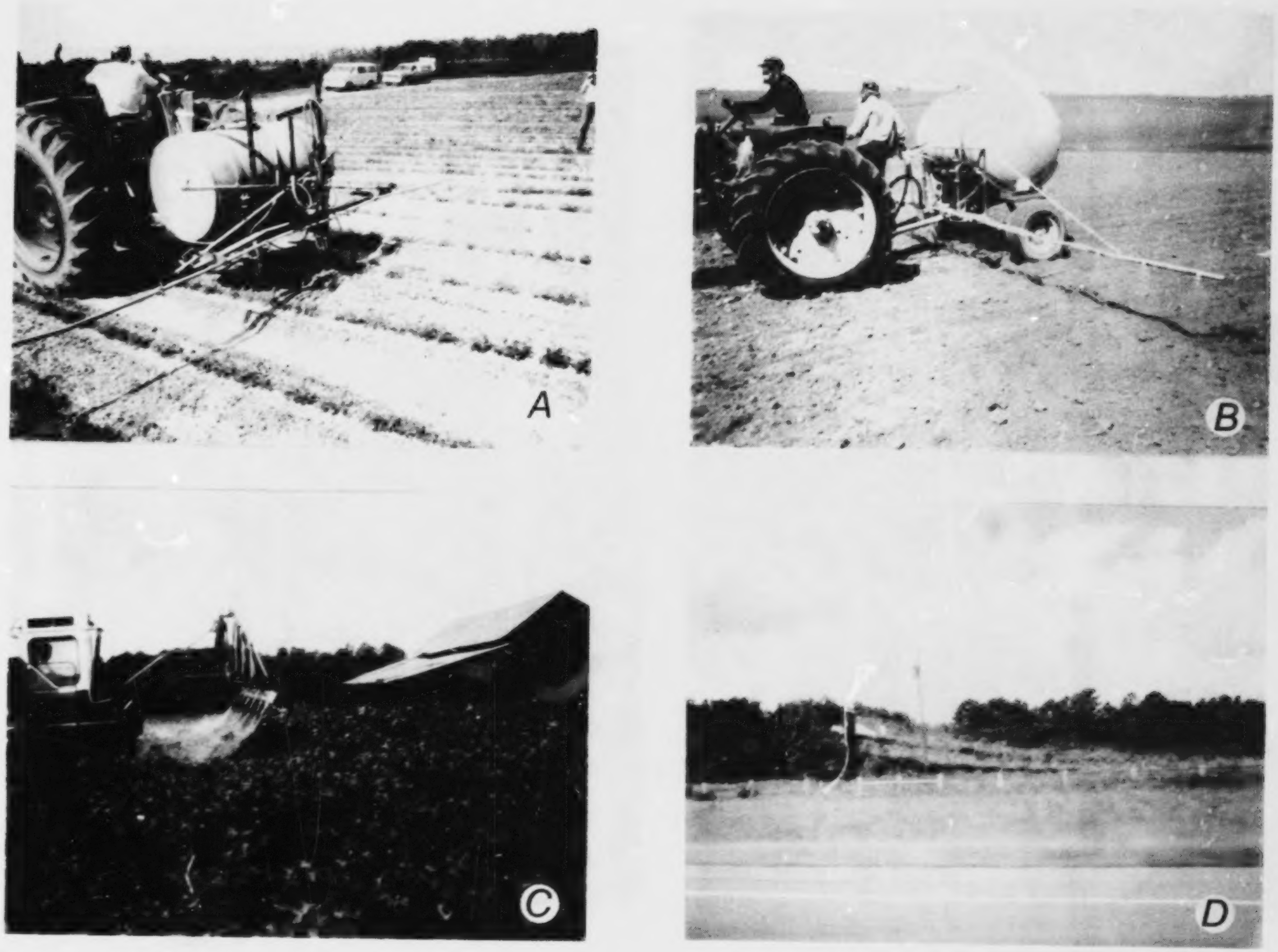


FIGURE 3.30. Examples of pesticide application methods include tractor-mounted (A), pull-type (B), electrostatic (C), aerial (D).

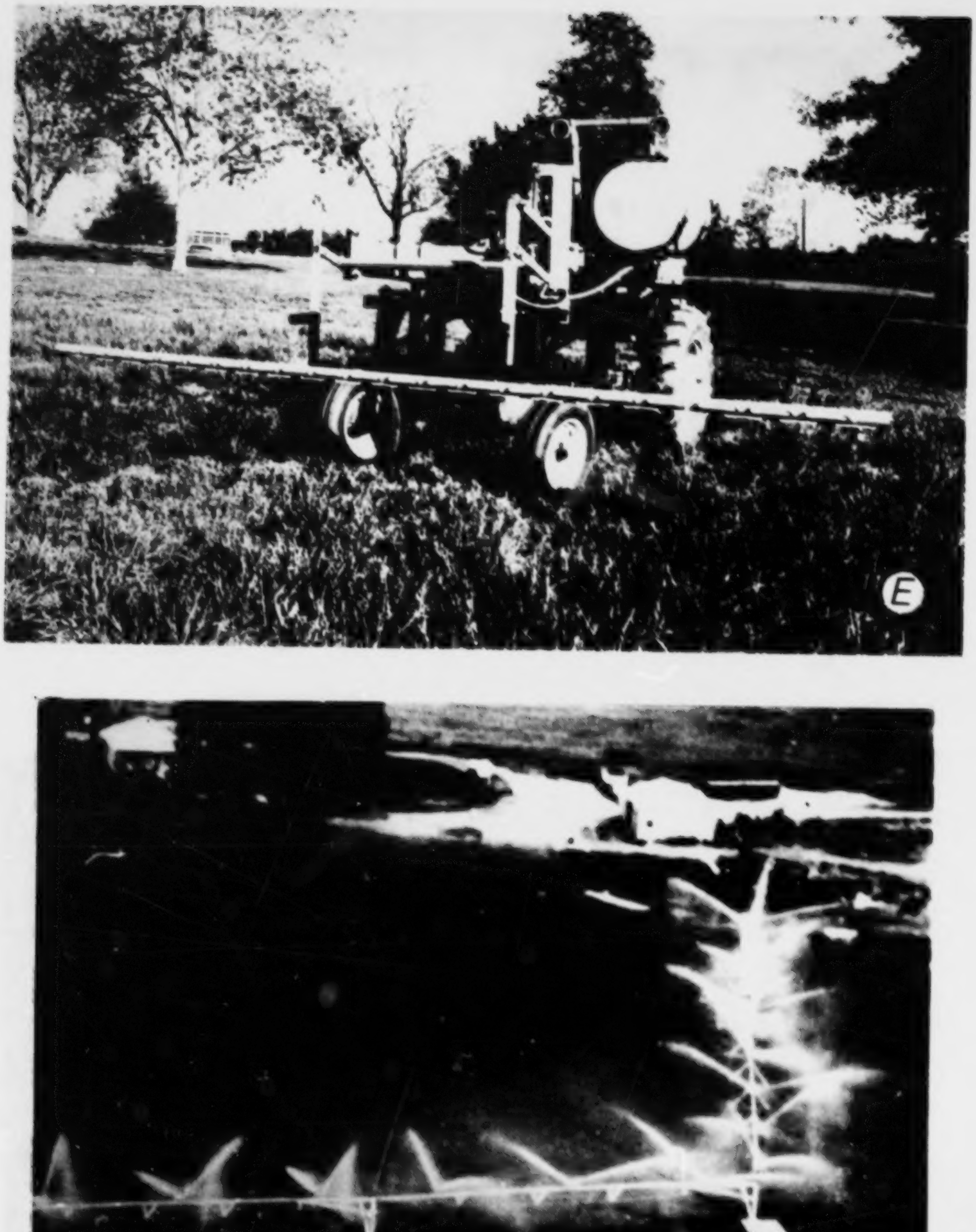


FIGURE 3.30 (Cont'd). Rope wick type (E) and chemigation (F).

irrigation process and eliminates additional field operations. Check valves should be utilized to prevent backflow of chemicals into water sources (wells, reservoirs, ponds, rivers, etc.) in the event of equipment failure. Wiese (1977) gives an excellent review of various herbicide application techniques, covering both small plot sprayers and conventional field equipment. For the purpose of this manual, discussions will be limited to the type of equipment used in actual field production situations. Very small plots and associated equipment are not recommended (see Section 3.2.1 on the minimum recommended field size). Weise (1977) indicates that all sprayers have the following essential characteristics:

1. A tank (Fiberglas® or stainless steel) for mixing and holding liquid spray material that is dispensed through a strainer to separate foreign material.
2. An energy source to propel or discharge the liquid spray from the tank consisting of a mechanically driven pump (nylon, rubber roller, gear, centrifugal, diaphragm or piston).
3. A pressure regulator to adjust and control spray pressure and discharge volume from tank.
4. An agitator to provide constant and uniform mixing of the chemical in the tank. Mixing is achieved by a return flow of liquid from the pressure regulator through agitator and by-pass lines.
5. A spray boom and system of nozzles constructed of flexible hose with angle iron support or a pipe with nozzle assemblies attached at specified distances for uniform distribution (overlap) over soil or plant surfaces. Nozzle type and height should be adjusted according to the type of application.

The amount of chemical actually applied to the target site depends on the method of application. Aerial application usually results in greater losses due to increased drift potential. Factors that influence drift losses are: wind velocity, pump pressure, nozzle angle, time of application, nozzle type, droplet size, formulation and nozzle height above the ground (Shoemaker and Harris, 1979). Shoemaker and Harris also show that four to five times more drift occurs from aerial application compared to high clearance ground sprayers. In addition, drift losses are greater for insecticides because the applications are usually at high pressure with small droplet sizes (Shoemaker and Harris, 1979). In regard to chemigation, application and runoff losses are virtually unknown. As new or novel techniques are developed, their impact on soil deposition should be determined.

Whatever application procedure is used, it is important to determine the actual amount of pesticide that reaches the field site. In the case of a foliar-applied pesticide, the distribution of chemical between the foliage and soil must be determined. This can be accomplished by monitoring actual amounts received by the soil and foliage. Monitoring techniques are discussed in Section 3.10. Careful calibration of application equipment should be conducted as a check on the monitoring process.

3.9.1 Liquid Sprayer Calibration

Calibrating the application equipment is an important step for pesticide runoff studies because the actual amount applied to the field site must be accurately known. Prior to the calibration exercise, nozzles must be examined examined to assure that they are in good condition and are adjusted to proper height and spacing for uniform coverage. Pump shaft seals, hoses, nozzles and valves must be checked for leaks. Several steps are involved in the calibration. These are included in the following example for broadcast spraying of a liquid formulation.

Example--Overall sprayer calibration involves three separate calibration steps; one for tractor speed, one for sprayer delivery rate, and one for tank mix concentration. Tractor speed is calibrated in terms of time to traverse a unit area, and therefore includes boom width as a factor. Sprayer delivery is measured in terms of volume delivered per unit time and tank mix is in terms of chemical mass per unit volume. Combining these factors results in the desired mass per unit area calibration:

$$\begin{array}{ccccccc} \text{Tractor speed} & & \text{Nozzle delivery rate} & & \begin{array}{c}\text{Tank mix}\\ \text{concentration}\end{array} & & \begin{array}{c}\text{Desired}\\ \text{calibration}\end{array} \\ \dfrac{\text{time}}{\text{unit area}} & \text{X} & \dfrac{\text{volume}}{\text{unit time}} & \text{X} & \dfrac{\text{mass}}{\text{unit volume}} & = & \dfrac{\text{mass}}{\text{unit area}} \end{array} \qquad (3.1)$$

Many pesticide labels express recommended application rates in the English system of units. Conversion to the metric units has been slow. For this reason, example sprayer calibration calculations will be duplicated for each system of units.

In English units, Equation 3.1 becomes:

$$\begin{array}{ccccccc} \text{Tractor speed} & & \text{Nozzle delivery rate} & & \begin{array}{c}\text{Tank mix}\\ \text{concentration}\end{array} & & \text{Desired calibration} \\ \text{sec acre}^{-1} & \text{X} & \text{gal sec}^{-1} & \text{X} & \text{lb gal}^{-1} & = & \text{lb acre}^{-1} \end{array} \qquad (3.2)$$

Similarily, in metric units:

$$\text{sec ha}^{-1} \;\text{X}\; \ell\ \text{sec}^{-1} \;\text{X}\; \text{kg}\ \ell^{-1} = \text{kg ha}^{-1} \qquad (3.3)$$

The targeted application rate is usually specified for a given set of field circumstances. For example, the herbicide metolachlor might be recommended for a peanut crop at the rate of 3.00 lb acre^{-1} (3.36 kg ha^{-1}). At least one of the factors in Equation 3.1 must therefore be continuously adjustable so that an exact rate of 3.00 lb acre^{-1} can be obtained. Because tractor speed is limited by a finite selection of gear ratios and nozzle delivery rates by available nozzle sizes, the tank mix concentration term is best suited for continuous adjustments. Although it is true that tractor speed can be regulated by engine rpm as well as gear ratio, rpm should be set at governor speed to assure constant and repeatable performance in field operation. Likewise, nozzle delivery rates could be varied as a function of pump pressure, but optimum nozzle operation cannot always be obtained if pressure is varied over wide limits. Pump pressure also is influenced by engine rpm and it is best that both these factors are fixed at the outset. Pressure should be set to give optimum nozzle performance, rpm should be set to governor speed, nozzles should be selected for adequate volume delivery to assure uniform coverage, and gear ratio should be selected for a reasonable and convenient field working speed. After these factors are fixed, the exact application rate is obtained by adjusting the tank mix concentration.

3.9.1.1 Tractor speed calibration

Tractor speed is calibrated by measuring the time required to traverse a measured distance in a field. This distance is multiplied by the width of swath covered by the spray boom to obtain a time per unit area calibration. During this test the tractor should be operated (from a running start) at full governor speed rpm in the gear selected for spraying and should have the sprayer attached and pump running as if under actual operation in the field. It is convenient to select the test run distance such that exactly 0.100 acre or other simple fractional area (0.1 ha) is covered in the test.

For example: assume 4-row equipment and a 36-in. row spacing. In this case the boom would spray a 12-ft swath. Under these conditions a linear distance of $\underline{363\text{ ft}}$ $\left(\frac{43{,}560\text{ ft}^2/\text{acre}^{-1}}{12\text{ ft spray swath}} \times 10^{-1}\right)$ would be required to cover 0.100 acre of area. A test course of this distance should be staked off. Elapsed times required for the tractor to traverse the course should be measured several times using a stop watch. Small variations are permissible due to slippage, etc., but enough trials should be performed to support a good statistical average. Assume an average time of 51 sec resulted from this test. The tractor speed calibration would then be 51 sec per 0.100 acre or 510 sec per acre.

The same example in metric units would involve 4 rows at 0.914 m spacings or a total swath of 3.66 m. A linear distance of 273 m $\left(\frac{10^4\text{ m}^2\text{ ha}^{-1}}{0.915\text{ m}} \times 10^{-1}\right)$ would be required to cover 0.100 ha. Since a distance of 273 m would probably be inconvenient an equivalent test track of 27.3 m based on a 0.010 ha area might be substituted. Assuming the tractor required an average of 12.6 sec to traverse this distance, the tractor speed calibration would be 12.6 sec per 0.010 ha or 1260 sec per ha.

3.9.1.2 Nozzle delivery rate calibration

After nozzle and pressure specifications have been selected, a test should be performed to determine nozzle delivery rates. This test should be performed with tractor engine rpm (pump rpm) and pressure regulator settings as to be used under actual operating conditions and the same as those used in the tractor speed trials (Section 3.9.1.1). Nozzles should be calibrated in terms of volume per unit time delivery rates. All nozzles should be included in this test and individual delivery rates should be compared for uniformity. Times required to deliver unit volumes from the individual nozzles should be measured and recorded in several trials. Once a set of suitable average times have been determined and are found to be uniform, an overall average for all nozzles should be calculated. This value should then be multiplied by the number of nozzles on the boom to arrive at a final calibration factor. These tests may be conducted with only water in the spray tank unless there is reason to believe substantial viscosity changes are expected when the formulation is present.

For example: assume the 4-row equipment noted earlier is outfitted with a 12-ft boom using 7 nozzle assemblies spaced at 20.5 in. intervals. One gallon containers should be held under each nozzle and times for complete filling measured by stop watch. Selected pressures, rpm, etc., should be maintained during the test. Assuming the mean nozzle delivery rate is found to be 1 gallon per 111.5 sec per nozzle or 0.00897 gal $\sec^{-1}$ per nozzle, the overall delivery rate for the whole boom would be 7 x 0.00897 = 0.0628 gal $\sec^{-1}$.

In metric units, the boom is 3.66 m wide and the 7 nozzles are spaced at 0.523 m intervals. One liter containers would fill in an average time of 29.5 sec and the nozzle delivery rate would be one liter per 29.5 sec per nozzle or 0.0339 $\ell \sec^{-1}$. All 7 nozzles would deliver at a combined rate of 7 x 0.0339 = 0.237 $\ell \sec^{-1}$.

3.9.1.3 Tank mix concentration calibration

The required tank mix concentration can be calculated from the tractor speed calibration factor (Sections 3.9.1.1), nozzle delivery rate calibration factor (Section 3.9.1.2), and the desired field application rate as follows.

$$\text{Tank mix concentration} = \frac{\text{Field application rate (lb acre}^{-1}\text{)}}{\begin{matrix}\text{Tractor speed factor} \\ \text{(sec acre}^{-1}\text{)}\end{matrix} \times \begin{matrix}\text{Nozzle delivery} \\ \text{factor} \\ \text{(gal sec}^{-1}\text{)}\end{matrix}} \quad (3.4)$$

Assuming: Tractor speed factor = 510 sec acre^{-1}

Nozzle delivery factor = 0.0628 gal $\sec^{-1}$

Desired application rate = 3.00 lb acre^{-1}

$$\text{Tank mix concentration} = \frac{3.00\ \text{lb acre}^{-1}}{(510\ \text{sec acre}^{-1})\ (0.0628\ \text{gal sec}^{-1})} \qquad (3.5)$$

$$= 0.0937\ \text{lb gal}^{-1}$$

A properly mixed tank solution should contain 0.0937 lb of chemical for each gallon of solution in the spray tank.

For the metric example:

Tractor speed factor = 1260 sec ha^{-1}

Nozzle delivery factor = 0.237 ℓ sec^{-1}

Desired application rate = 3.36 kg ha^{-1}

and

$$\text{Tank mix concentration} = \frac{3.36\ \text{kg ha}^{-1}}{(1260\ \text{sec ha}^{-1})\ (0.237\ \ell\ \text{sec}^{-1})} \qquad (3.6)$$

$$= 0.0113\ \text{kg}\ \ell^{-1}$$

A properly mixed tank solution would contain 0.0113 kg of chemical for each liter of solution in the spray tank.

Care should be taken to avoid ambiguity in expressing application rates. Rates may be expressed in terms of active ingredients or in terms of formulations. Either basis may be used, but should be used consistently throughout the calculation and tank mixing operations. Serious errors can otherwise result.

The volume of tank mix required for a given acreage can be calculated from the tractor speed and nozzle delivery rate calibration factors as follows.

$$\underset{\text{(time/unit area)}}{\text{Tractor speed}} \quad \text{X} \quad \underset{\text{(volume/unit time)}}{\text{Nozzle delivery}} = \frac{\text{Volume of tank mix}}{\text{unit area}} \qquad (3.7)$$

Continuing with the previous example:

$$510\ \text{sec acre}^{-1}\ \text{X}\ 0.0628\ \text{gal sec}^{-1} = 32.0\ \text{gal acre}^{-1} \qquad (3.8)$$

or, for the metric example

$$1260 \text{ sec ha}^{-1} \times 0.237 \ \ell \text{ sec}^{-1} = 299 \ \ell \text{ ha}^{-1} \tag{3.9}$$

Multiplications of these values by the number of acres (hectares) to be sprayed will yield the total tank mix volume required. A slight excess should be prepared. Spray tanks will not usually drain completely on rough ground without adversely affecting the spray pattern. Excess volume of solution remaining in the tank after spraying is completed should be measured. This will provide an additional check on the application rate actually delivered.

3.9.1.4 Cautions regarding tank mixes

Two or more chemicals can sometimes be mixed and applied together. Caution should be exercised, however, to assure that the formulations are compatible. Manufacturers normally supply this information for recommended mixtures. If other mixtures are considered, the operator should conduct tests to determine compatability.

3.9.2 Granular Applicator Calibration

The application of a granular pesticide requires that the applicator be calibrated to deliver a given weight of pesticide per distance of row (if banded) or to a known area (if broadcast). The calibration procedure is similar to the liquid sprayer calibration except that the tank mix factor does not apply. Some pesticides require incorporation into the soil and should be thoroughly mixed using some type of mechanical incorporator.

3.9.3 Timing of Application

The application of pesticides must be keyed to the normal planting operations and the crop growing season. The usual planting and harvesting dates for some important field and seed crops for each state are presented in Figures 3.31, 3.32, and 3.33. A more extensive compilation that includes some agronomic data is given in Table 3.7.

The time of day the pesticide is applied affects the amount of chemical delivered to the target area. The preferred application time is during the early morning when relatively little wind movement is observed and the soil temperature is near a minimum.

3.9.4 Field Safety

Experimental field work usually necessitates that several field personnel be present during, and immediately following, chemical applications.

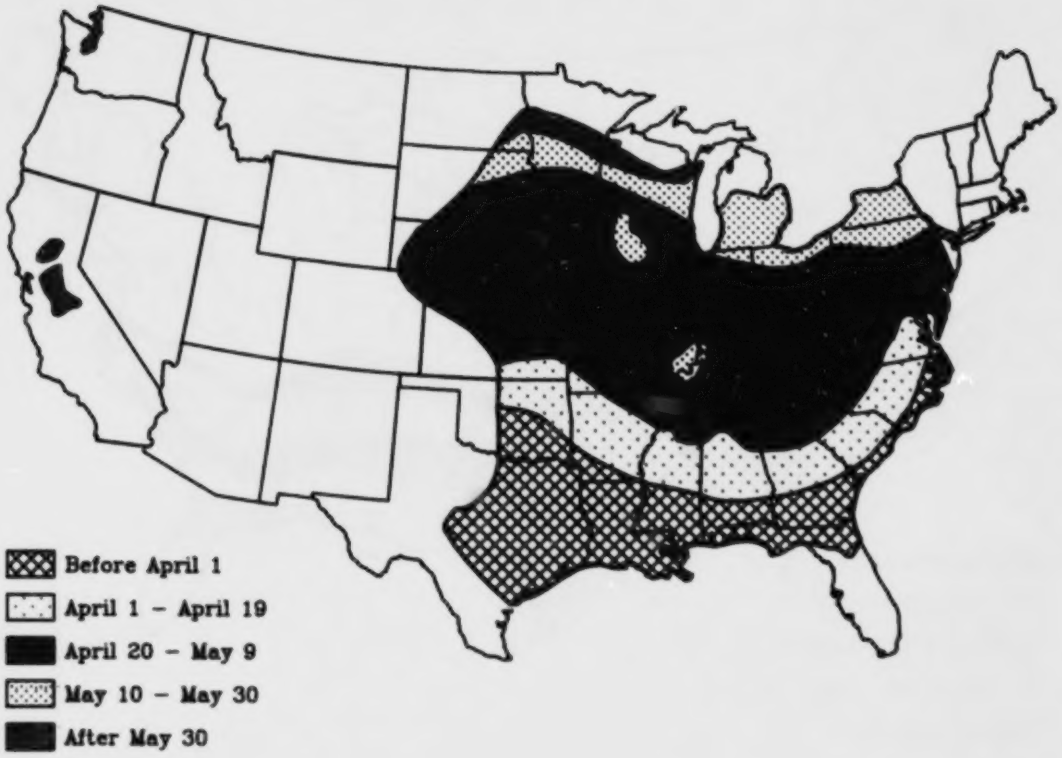


FIGURE 3.31. Usual starting dates of corn planting in United States (Burkhead et al., 1972).

Potential exposures to chemical spray drifts and vapors are high during this period. Field workers should utilize applicable forms of available safety equipment whenever possible. Respirators, protective clothing, and gloves are useful for this purpose. The usual cautions for safe operation of heavy machinery should also be employed.

3.10 PESTICIDE APPLICATION MONITORING

To follow pesticide persistence with time after application, it is important to know as accurately as possible the amount of pesticide that actually reached the target. The difference between the calibrated amount of applied chemical and the amount intercepted by the soil surface (as monitored by filter disc or other methods) should be small indicating field losses during application were insignificant. Inordinate discrepancies would be indicative of high drift losses, inaccurate calibration or inadequate sampling and measurement procedures. The time delay between chemical

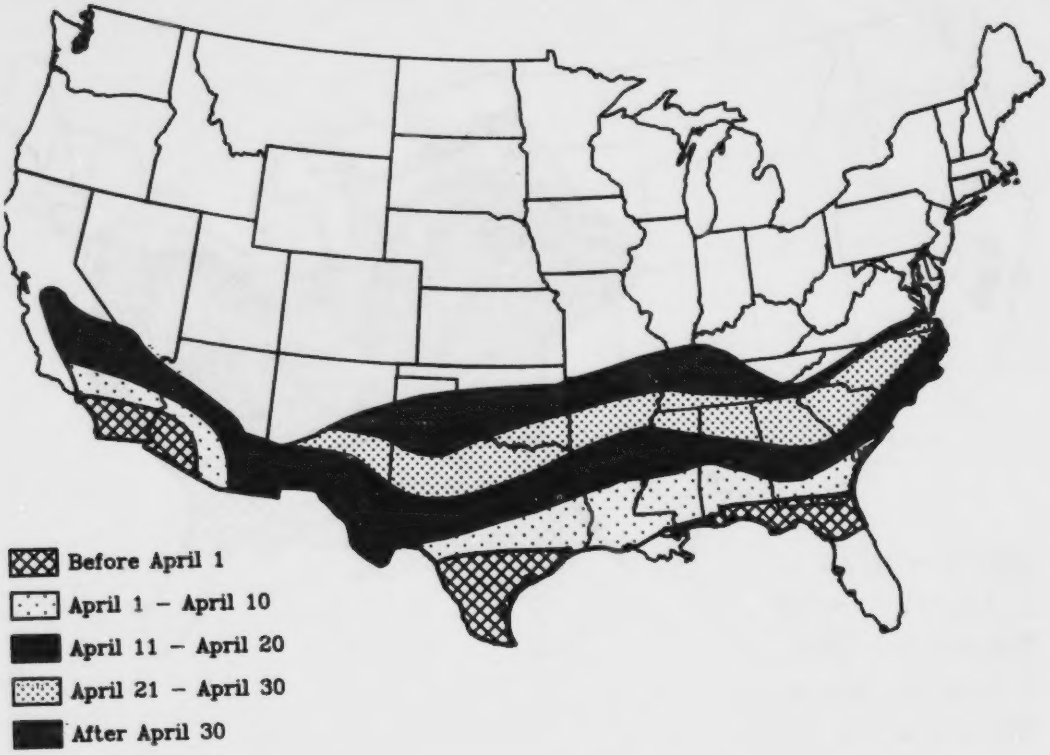


FIGURE 3.32. Usual starting dates of cotton planting in United States (Burkhead et al., 1972).

application and monitoring should be kept to a minimum so that losses from the field after application are not confused with application or monitoring problems. Some compounds have half-lives of only a few hours.

Because pesticides can be applied directly to the soil surface, incorporated in the soil, applied to plant foliage, or distributed between the plant and soil, different techniques are required to monitor these various application modes, see Table 3.8.

Several methods for monitoring herbicide application rates have been investigated by Smith et al. (1978). These include (1) the use of filter paper discs, (2) timing the sprayer during application and recording total spray time on the field, and (3) use of a surface soil sampler, Table 3.9. In addition, Smith et al. (1981), conducted a plot study with a foliar applied insecticide that required monitoring the application distribution between plants and soil to evaluate foliar washoff losses. Discussions on the various monitoring techniques are covered in Sections 3.10.1, 3.10.2, 3.10.3, and 3.10.4.

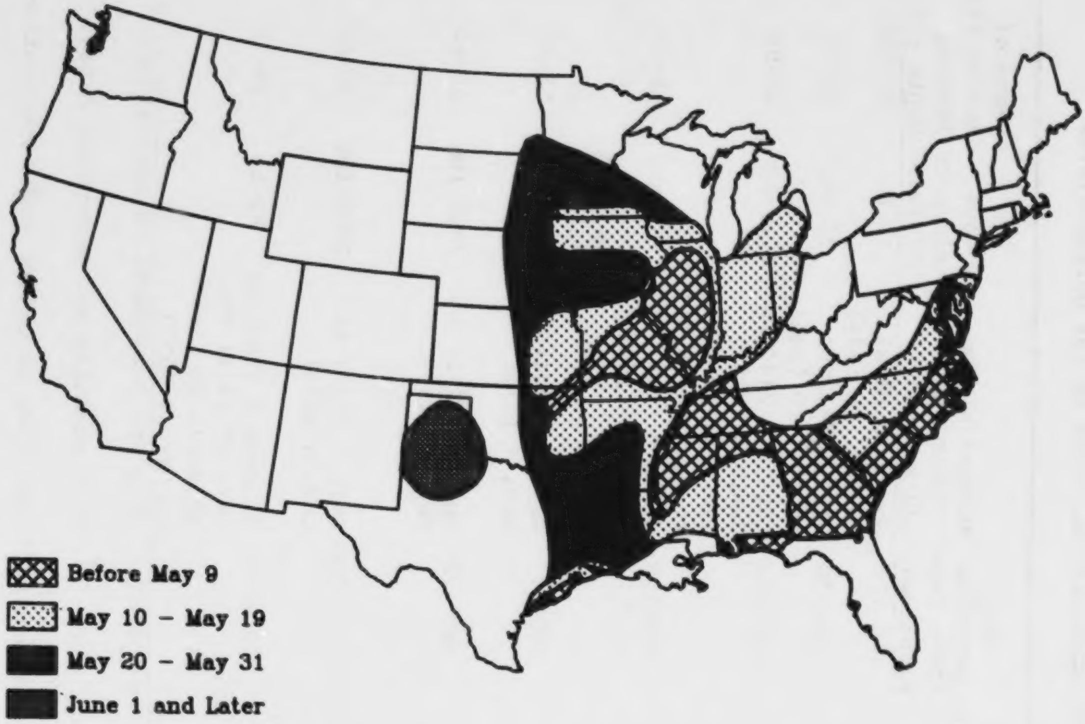


FIGURE 3.33. Usual starting dates of soybean planting in United States (Burkhead et al., 1972).

3.10.1 Filter disc method

This technique involves the use of filter discs (Whatman number 42 of 15 cm or greater diameter have been found to be acceptable) to intercept the liquid spray at the soil surface. Pesticide penetration tests through single filter discs have been checked and found to be negligible (Smith et al., 1978). For high volume spray application, two layers of filter disc should be used to eliminate potential bleed-through losses.

The optimum number of filter disc locations within the field will vary depending on the study design, as discussed in Section 3.7. When using ground application equipment, the area taken by the tractor tires must be recognized and eliminated from the sampling area because filter discs would otherwise be crushed by the tractor tires. Once filter disc locations are determined, a metal rod or similar tool can be used as a jig to aid in positioning the discs in the field prior to application (Figure 3.34).

TABLE 3.7. AGRONOMIC DATA FOR MAJOR AGRICULTURAL CROPS IN THE UNITED STATES (Carsel et al., 1984)

Crop	Representative States of Major Production[a]	Planting Window, Month, Day (Julian Day)[b]	Crop Emergence (Days from Planting	Crop Maturity (Days from Planting)	Harvest Window, Month, Day (Julian Day)[b]	Average Yield/Acre 1977-1979[c]	Range of Active Plant Rooting Depth (cm)
Corn	IA, IL, IN, NE, OH	April 25 (115) to June 15 (166)	5-15	110-130	Sept. 25 (268) to Dec. 10 (344)	110 bu	60-120
Soybeans	IA, IL, IN, MS, OH	May 1 (121) to June 25 (176)	5-15	110-130	Sept. 15 (258) to Dec. 10 (344)	35 bu	30-60
Cotton	TX, MS, CA, AZ, AR	March 1 (60) to May 25 (145) [TX to June 20 (171)]	5-15	110-130	Sept. 1 (244) to Jan. 15 (015) [TX Aug. 1 (213) to Dec. 20 (354)]	670 lbs	30-90
Wheat	KS, OK, CA, ND, MT, WA, MN, ID	Aug. 15 (227) to Oct. 25 (298) [WA to Nov. 20 (324), CA to Feb. 15 (046)]	5-15	200-225	June 15 (166) to Sept. 20 (263)	40 bu	15-30
Potatoes	Long Island NY, ME, ID, WA, CA, OR	April 1 (091) to May 1 (121)	5-15	150-170	Sept. 1 (244) to Oct. 1 (274)	335 cwt	15-45
Peanuts	GA, TX, AL, NC, VA	April 5 (095) to June 5 (156) [TX Mar. 31 (090) to July 20 (201)]	5-15	150-175	Aug. 10 (222) to Dec. 15 (349)	2550 lbs	30-60
Tobacco	NC, SC, TN, KY, VA	April 5 (095) to June 20 (171)	Planted in Field as Seedling	120-150	July 1 (182) to Oct. 1 (274)	2000 lbs	30-60
Grain Sorghum	TX, KS, NE	TX Mar. 1 (060) to July 1 (182) KS, NE May 5 (125) to July 1 (182)	5-15	120-150	TX July 1 (182) to Nov. 20 (324) KS, NE Sept. 20 (263) to Dec. 1 (335)	62 bu	15-30

[a] Bay, D. M. and Bellinghausen, R. P. Missouri Farm Facts. Missouri Department of Agriculture. May 1979.

[b] Burkhead, B. E., Max, R. C., Karnes, R. B., and Neid, E. Usual Planting and Harvesting Dates. USDA, Agricultural Handbook No. 283. 1972.

[c] Kirkbride, J. W. (Ed.). Crop Production Annual Summary. USDA, Crop Reporting Board Publication CrPr 2-1. 1980.

TABLE 3.8. SAMPLING TECHNIQUES FOR USE THROUGHOUT THE CROPPING SEASON

Sampling purpose	Sampling technique
Background monitoring (prior to tillage and pesticide application)	Split-tube core sampler or hand auger
Monitoring applications on bare soil	
- liquid broadcast on surface	Filter disc* or surface soil sampler
- liquid broadcast incorporated	Surface soil sampler
- granular broadcast and/or banded in row	Surface soil sampler or aluminum cans
Monitoring applications directed to plant foliage	
- Plant foliage	
a) row crop	Whole plant
b) tree	Leaf samples
- Soil	Filter disc
Post application monitoring	Surface soil sampler
Post runoff event monitoring	Split-tube core sampler or hand auger

*Filter disc are preferred unless soil sampling using surface soil sampler is planned for daily observations until first rainfall event.

TABLE 3.9. HERBICIDE APPLICATION RATES AS MONITORED BY VARIOUS TECHNIQUES (kg/ha), 1975 (Smith et al., 1978)

Watershed	Sample type	Atrazine	Cyanazine	2,4-D	Paraquat	Diphenamid	Propazine
P1	Filter disc	NA*	NA	NA	1.66	NA	1.66
	Nozzle (timing)				1.29		1.78
	Surface soil sampler						
P2	Filter disc	1.54	1.61	1.68	1.93	NA	NA
	Nozzle (timing)	1.65	1.44	1.12	1.96		
	Surface soil sampler	1.33	1.26		2.00		
P3	Filter disc	NA	NA	NA	1.84	2.31	NA
	Nozzle (timing)				1.45	3.36	
	Surface soil sampler						
P4	Filter disc	1.45	1.35	1.55	1.75	NA	NA
	Nozzle (timing)	1.81	1.55	0.86	0.86		
	Surface soil sampler	1.55	1.52		3.70		

*NA = Not applied.

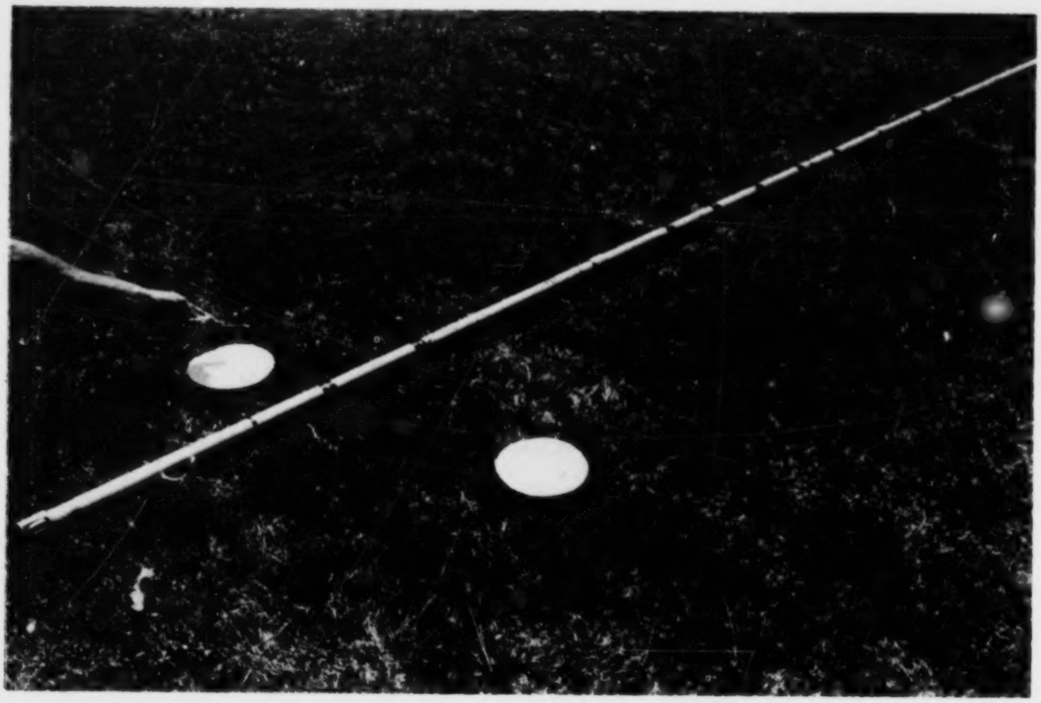


FIGURE 3.34. Filter disc, jig, and "hold down" wire.

Because the preferred application time is in the early part of the day, field work to position filter disc should be initiated at an early hour. This process often requires considerable effort and should be carefully planned so that adequate manpower is available on the site. If there are concerns for wind moving the filter discs prior to or during application, simple "hold down" wires can be made using small diameter wire (Figure 3.34). During application, the sprayer passes over the discs, then each disc is immediately removed (to reduce losses by volatilization) and sealed in a glass jar. One-pint Mason jars with lids lined with aluminum foil are convenient for this purpose. Jars should be labeled as to exact location in the field. Samples may be kept in ice coolers during transport to analytical laboratory. At the laboratory, samples should be kept frozen until analysis. Analytical results for each disc are usually reported as mg/disc. The following is an example calculation using an 18.5 cm filter disc.

1. Determine surface area (πr^2) of the disc.

   Example: 18.5 cm (0.607 ft) diameter disc

Radius (r) = 9.25 cm = 0.304 ft

$$\text{Disc area} = (3.14)\ (9.25)^2 = 269\ \text{cm}^2/\text{disc}$$

$$\text{or} \qquad = (3.14)\ (0.304)^2 = 0.290\ \text{ft}^2/\text{disc}$$

2. Determine application rate (lb/acre)

$$\frac{\text{(mean) mg pesticide/disc}}{0.290\ \text{ft}^2/\text{disc}} \times \frac{1\ \text{lb}}{454\ \text{g}} \times \frac{1\ \text{g}}{1000\ \text{mg}} \times \frac{43{,}560\ \text{ft}^2}{\text{acre}} = \tag{3.10}$$

lb pesticide/acre

$$\text{or} \quad \text{mg pesticide/disc} \times 0.331 = \text{lb pesticide acre}^{-1}$$

Similarily, the application rate in kg ha^{-1} would be

$$\frac{\text{mg pesticide/disc}}{269\ \text{cm}^2/\text{disc}} \times \frac{1\ \text{kg}}{10^3\ \text{mg}} \times \frac{10^4\ \text{cm}^2}{\text{m}^2} \times \frac{10^4\ \text{m}^2}{\text{ha}} = \text{kg pesticide ha}^{-1} \tag{3.11}$$

$$\text{or mg pesticide/disc} \times 372 = \text{kg pesticide ha}^{-1}$$

3.10.2 Field Timing Method

This is a simple and easy method for monitoring application rates and is useful in conjunction with other methods as a check. The total time the sprayer is in operation on the field site is recorded (time required for tractor to turn at end of rows is not included). Determination of the total application by this method requires the collection of a nozzle sample. Both the concentration of pesticide in the sample and the nozzle delivery rate should be determined. Nozzle delivery rate can be determined as described in Section 3.9.1.2.

3.10.3 Soil Sampling Methods

Various sampling techniques have been investigated for obtaining soil samples immediately following pesticide application, i.e., split-tube core sampler, and surface soil sampler. Smith et al. (1978) identified several problems in verifying application rates using a split-tube samplers in loose soils. These included: (1) core compression during sampling, (2) lack of depth zone definition, (3) inter-depth zone contamination, and (4) bulk density pertubations.

The surface soil sampler shown in Figure 3.35 produced reliable data for sampling loose soil. These data agree well with measurement via filter paper (Table 3.9) and have been used successfully in several field runoff

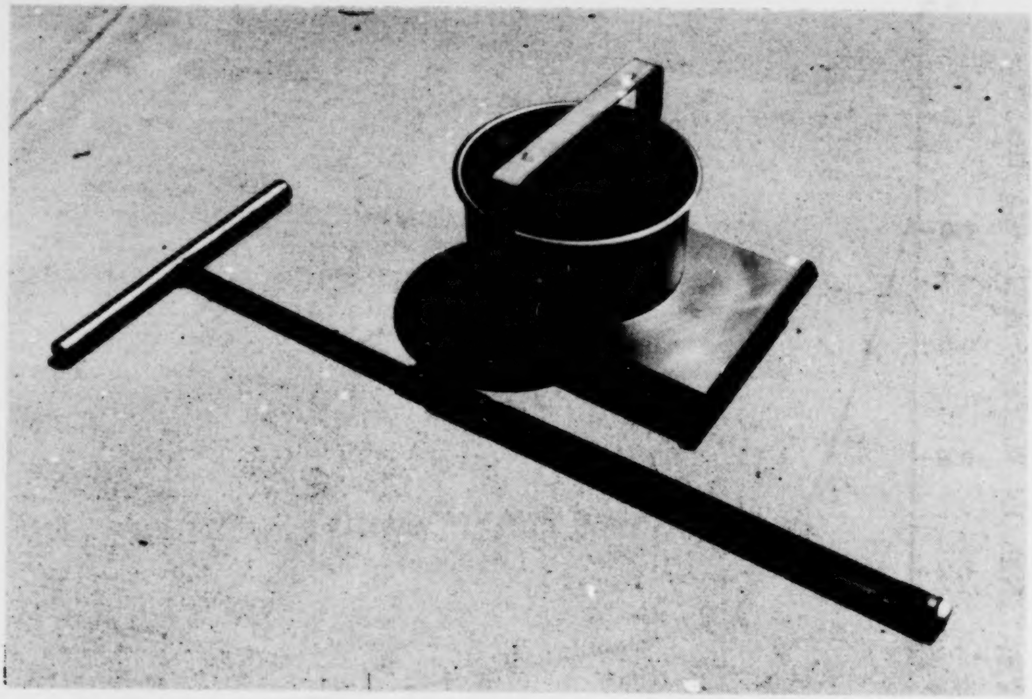


FIGURE 3.35. Surface soil sampler and 1.9 cm split-tube sampler.

studies. Design of the sampler with transfer funnel and support stand is shown in Appendix E. The sampler is also suitable for use in post application monitoring. Figure 3.36 illustrates typical results of surface area sampling over a 7-day interval between application day and the first runoff event showing a sharp break in the disappearance rate for atrazine. Precision of this quality could not have been obtained with other samplers.

When using the sampler, it is pressed into the soil to desired depth (2.5 to 5.0 cm for monitoring surface-applied pesticides). Maximum depth of sampling is 10 cm. Soil near the sampler is pulled away to allow the insertion of the cutting blade through its slot. The soil in the sampler is transferred to a 1-gallon, wide-mouth bottle using a transfer funnel (see Appendix E), then weighed, and blended using a twin-shelled blender. A subsample is taken for pesticide residue analysis and soil water determination. The amount of pesticide residue remaining in the soil can be expressed on a unit area or, optionally, on a unit volume basis depending on the particular application. Either way, the ambiguity of using an unstable bulk density term in mass calculations is eliminated through use of the surface sampler.

If a surface soil sampler is not available, shallow aluminum cans can be inserted into the soil to obtain full-can core samples. Aluminum cans

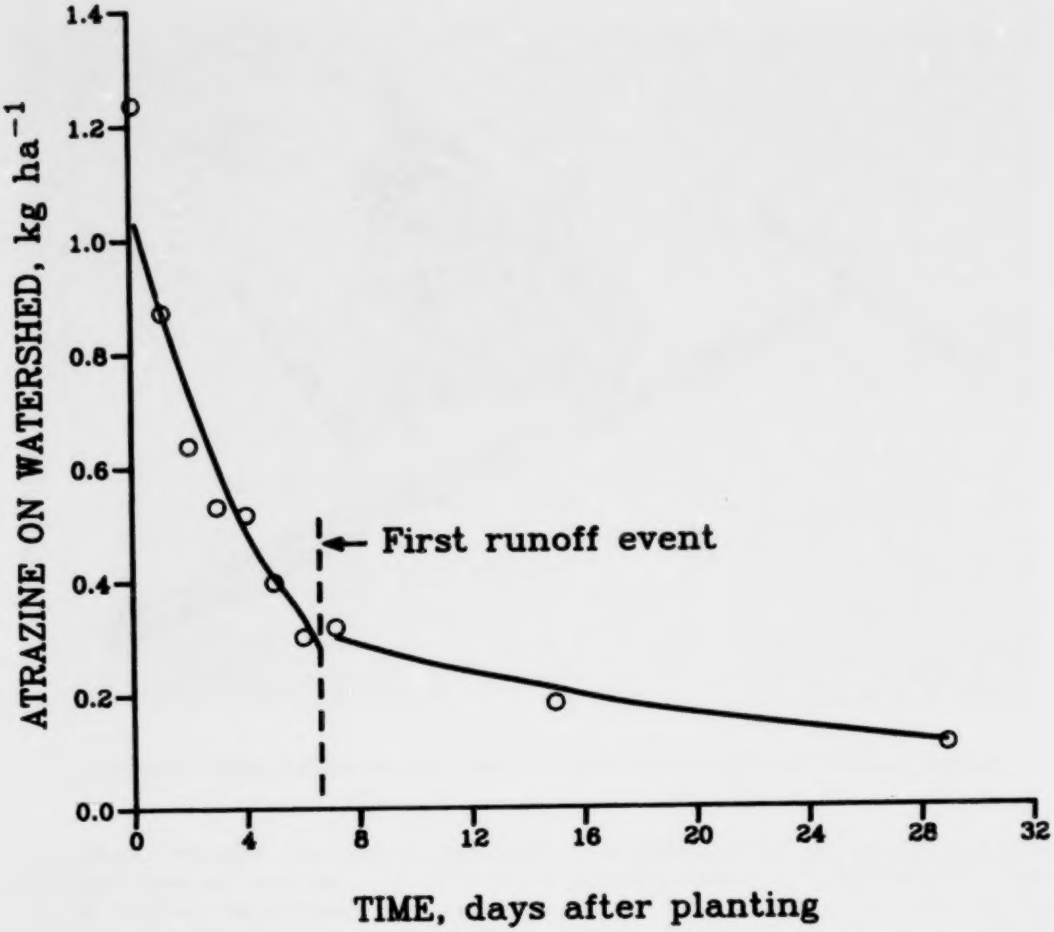


FIGURE 3.36. Atrazine persistence in top 2.5 cm of soil for a watershed in a Cecil soil near Watkinsville, GA.

approximately three and one-half inches in diameter and two inches deep are convenient for this purpose. The sample volume is known from the dimensions of the can. Wet weight is determined directly and total dry weight is determined from separate soil moisture content analysis.

3.10.4 Plant-Soil Application Distribution Measurements

In the case of foliar applied pesticides, the application distribution between the plants and soils is an important measurement. The amount intercepted by plant foliage reduces the amount that reaches the soil upon application and will have an impact on runoff losses. Smith and Carsel (1984), have demonstrated this effect in simulation studies of several insecticides applied to cotton.

Application distributions can be determined using filter discs to monitor the fraction received by the soil (see Section 3.10.1) and plant tissue samples to monitor the fraction intercepted by the foliage. For row crops, whole-plant tissue sampling is preferred. Individual plants are wrapped in aluminum foil, labeled, sealed with tape, placed in ice coolers for transport to the analytical laboratory, then frozen and stored until analysis.

When the experimental site is some type of orchard, there are a few additional facets of the design that merit consideration. Sampling that is done to determine the amount of compound reaching the soil surface during application should account for the various areas that might receive systematically varying amounts of the compound. For example, ground area directly beneath the canopy, area between trees, and areas where the spray rig travels are likely to intercept different average amounts of the compound and have differing variabilities. Relative areal measurements should be obtained and a sample design such as proportional allocation could be used so that a properly weighted estimate of the orchard total can be obtained.

Sampling to determine amounts of the compound that adhere to the trees will usually involve sampling a number of leaves from a number of randomly selected trees. The leaf sampling should account for possible variation from top to bottom of the tree and from outside to inside. Generally, the objective is to obtain an unbiased estimate of the average amount per leaf or unit area of leaf. Sample sizes can be chosen to provide any needed precision.

3.11 SOIL SAMPLING AFTER RUNOFF EVENTS

Soil samples are collected and analyzed for estimating pesticide residues at various times and depths in the soil. These results are used for determining degradation rates and leaching, runoff and erosion losses. Most models require as input first-order degradation rate constants based on average pesticide residues intergrated over the entire soil profile.

A single sampling technique is not available that is suitable for all sampling needs. Table 3.8 provides a summary of preferred sampling techniques for various purposes.

The period between application and the first runoff event is a critical time for sampling. Degradation during this period can be extremely rapid. Figure 3.36 shows a rapid decline in atrazine concentration during a 7-day rainless period following application. The surface soil sampler or aluminum cans are most suitable because they take volume samples. This eliminates the need for estimating bulk density to facilitate mass balance computations. Bulk density in freshly tilled soil is highly variable and difficult to measure.

The 1.9-cm, split-tube core sampler is a conventional method of obtaining soil samples. As indicated earlier, this method is not suitable for monitoring application rates in loose soil, but is reliable for background sampling and post-rainfall events once compaction or soil settling has taken place. To obtain sufficient quantity of soil for analysis, multiple core samples are required. These should be randomly selected samples from a given area and composited. Various sampling depths have been used in previous studies. Typical soil sampling depth increments are 0-1 1-7.5, 7.5-15, and 15-30 cm, for characterization of pesticide residue content with depth. For some chemicals, it may be advantageous to concentrate sampling efforts in the upper surface zone. In hot, dry conditions, some surface applied chemicals degrade very rapidly in the upper crust at depths of less than 1 cm. It is important for soil samples to be taken after each runoff event for all depths and at each sampling segment within the field to evaluate residue remaining and vertical movement and to obtain mass balance calculations. Fields typically reach optimum moisture content for sampling within 1 or 2 days after rainfall events. Sampling can be extremely difficult when soil moisture content is inappropriate. Excess contamination usually results when sampling extremely dry soils. Very high moisture contents usually prevent field entry.

Split-tube sampling is accomplished by pushing the sampler into the soil to the desired depth and gently pulling the sampler upward out of the hole. A spatula can be used to trim away the exterior portion of the soil core to minimize potential contamination from the dry surface soil. The resulting core can be divided into the desired depth increments.

Other methods of soil sampling include the use of hand augers. A variety of sizes is available, as shown in Figure 3.37. Whatever size is selected for use, it should be used consistently because the auger size can have an effect on the results. These samplers are of sufficient size that a single soil core sample for a selected site provides an adequate volume of sample for analysis. Care must be taken to eliminate potential contamination. The central part of the auger core is least likely to be contaminated. The extreme upper and lower part of the core should be discarded and the central part used for the sample. Sampling depth increments of less than 6 inches (15 cm) is not practical.

It is helpful to construct a sample tray for carrying sampling cans that organizes samples by depth as shown in Figure 3.38. The soil samples can be stored in 3-inch diameter aluminum cans. Plastic containers should not be used because of potential sorption problems. Sample labels should include information on sample ID number, date, depth, and any appropriate field notes. It is also prudent to establish sampling record sheets similar to the one shown in Figure 3.39. The sampling cans can be sealed with plastic tape to preserve moisture content and secure the lid. The samples can be placed in ice coolers for transport to the laboratory.

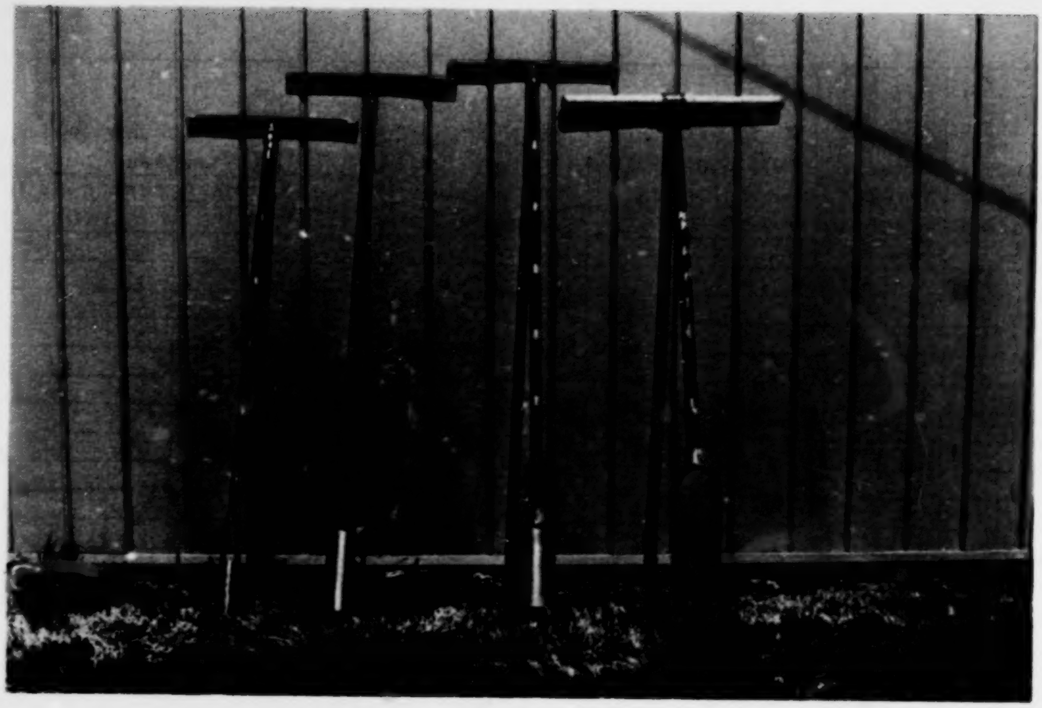


FIGURE 3.37. Various size hand augers.

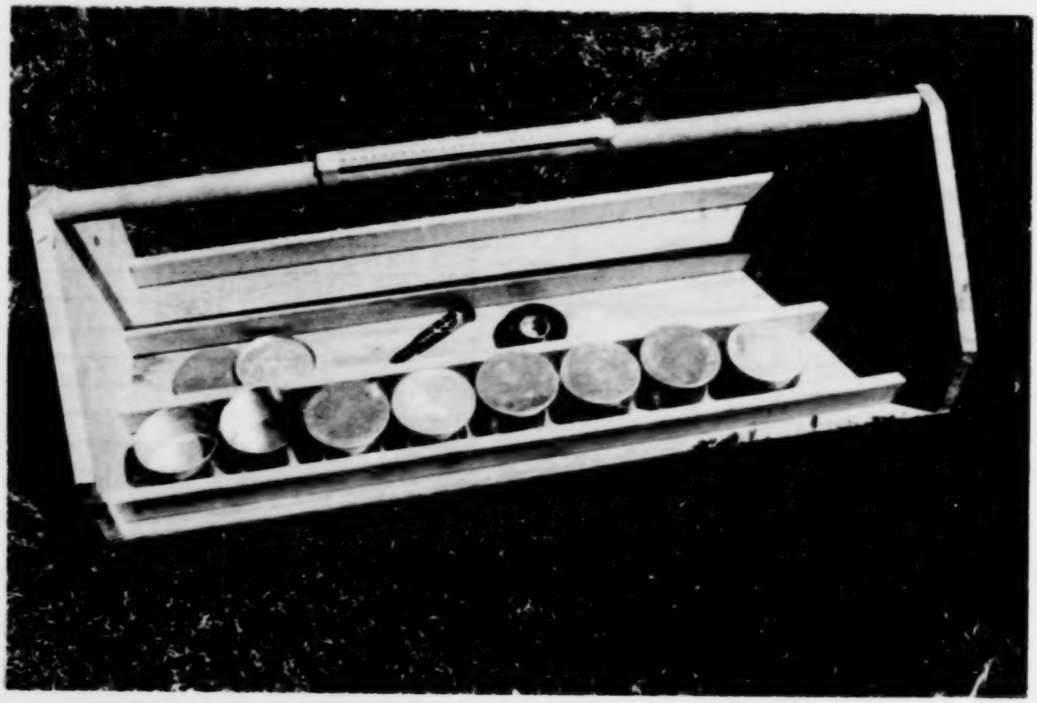


FIGURE 3.38. Carrier tray with aluminum soil sample cans.

Date Sample Obtained	Days After Planting	Sample Number	Sampling Depth (CM)	Site Number	Samples Taken by (Name) and Sampling Remarks	Results of Chemical Analyses	
						Pesticide A (ppb)	Pesticide B (ppb)

FIGURE 3.39. Example of soil sampling record keeping.

3.12 RUNOFF SAMPLING

Runoff sampling equipment and techniques were discussed in Section 3.3.3. It is important that runoff samples are removed from the field soon after runoff events so that sampling equipment is ready for new events. Samples also should be analyzed for pesticide residues as soon as possible to minimize errors due to degradation losses. Each sample should be labeled, consistent with record keeping sheets similar to the example shown in Figure 3.40. Runoff samples are collected for each event after application until the parent pesticide decreases in concentration to a level below the detection limit.

If information on particle size distribution is not desired, calcium chloride can be pre-added to sample containers before they are placed in the collection devices. This will promote flocculation of sediments and aid in making phase separation.

Runoff samples can be transported to the laboratory in ice coolers and stored in a refrigerator at 4°C until processed. If both chemical (pesticide residue) and physical (particle size distribution) analyses are desired, runoff samples should be subdivided. Fleming and Leonard (1973) designed a sample splitter to subdivide large-volume samples containing sediment. Separate pesticide analysis should be performed in the sediment and water phases and sediment weights should be determined. The relative effort exerted in analyzing either the sediment or solution phases should reflect the main transport mode of the pesticide. Strongly sorbed pesticides tend to be transported in the sediment phase and weakly sorbed pesticides move primarily in the solution phase.

3.12.1 Particle Size Analysis and Enrichment Ratio

Methods for conducting particle size distribution analysis were discussed in Section 3.5.3. Automated methods also are available. Johnson and Baker (1982) used a Sedigraph 5000® particle size analyzer to determine particle size distribution in runoff samples from an Iowa watershed. Information on particle size distribution in runoff is important because fines (silt, clay) normally have enriched pesticide contents. This enrichment effect results from the increased surface areas, cation exchange capacities, organic carbon contents of the fine fractions. This is compounded by the fact that fines also are enriched in runoff relative to the parent soil. Enrichment ratios are discussed in Section 3.12.4.

3.12.2 Sediment Organic Carbon

Organic carbon content of runoff sediments is important because of the influence organic carbon has in determining overall pesticide sorption (Karickhoff, 1983). The carbon content of eroded sediments can vary with time during runoff events. Carbon contents can be determined as outlined in Section 3.5.4.

Date (MMDDYY) Watershed Flume Size ft.

Stage Time HHMM	Stage Height, M	Sample Number	Sample Time HHMM	Sediment Concentration, g/ℓ	Rain Time HHMM	Rain Level, cm

FIGURE 3.40. Example of runoff sampling record keeping.

3.12.3 Sediment Cation Exchange Capacity

The cation exchange capacity (CEC) is an expression of the number of cation adsorption sites per unit weight of soil or sediment, expressed in milliequivalents per 100 grams of oven-dry soil. CEC influences sediment sorption capacity; particularly for cationic or polar compounds. Methods for determining CEC in both arid land and acid soil is presented by Rhoades (1982).

3.12.4 Enrichment Ratio

Enrichment ratios of several types are used in some of the current erosion and pesticide runoff models. These ratios originate from the fact that eroded sediments tend to have higher percentages of fines (silt and clay) than the soil from which they came. Because the smaller size fractions usually have higher specific surface areas, cation exchange capacities and organic carbon contents, they also have increased sorption capacities and tend to contain higher concentrations of pesticide. For highly sorbed pesticides (which are transported primarily in the sediment phase), these natural enrichment processes can have a dramatic influence on pesticide transport. For studies involving compounds that partition strongly toward the sediment phase (high K_p), the enrichment process should be evaluated. Runoff losses of weakly sorbed compounds (K_p generally less than 5) are not sensitive to enrichment ratios because the primary mode of transport is through the solution phase. These criteria should be considered in determining whether enrichment ratio measurements should be conducted in a given study.

Examples of enrichment ratios used in some models include:

$$\text{Specific surface area enrichment ratio} = \frac{\text{specific surface area of eroded sediments}}{\text{specific surface area of whole soil}}$$

This ratio is calculated by accounting for surface area contributions from sand, silt, clay and organic carbon fractions and is used in the erosion component of the CREAMS model (Foster et al., 1980).

An organic matter enrichment ratio (τ_{om}) is used in the PRZM model (Carsel et al., 1984) and is defined by

$$\ln(\tau_{om}) = 2 + 0.2 \ln (\psi_e/A_w)$$

where ψ_e refers to soil loss as calculated from the Modified Universal Soil Loss Equation (MUSLE) used by Williams and Berndt (1977) and A_w is the area of the watershed.

3.12.5 Equipment Maintenance and Monitoring

The importance of having field equipment checked and serviced routinely to assure proper operation can not be over-emphasized. It is advisable (if not necessary) to have an operator on site during major events (runoff events that occur soon after application) to see that automatic samplers are not allowed to malfunction. This is especially important in new systems which have not been fully debugged. New installations are often untrustworthy. Samplers frequently become clogged with crop residues and other trash. Usually, only minimal on-site effort is required to prevent major data losses. On-site personnel visits are essential.

The on-site operator also should occasionally collect manual runoff samples for comparison as an added check on the automatic equipment. Johnson and Baker (1982) added sampling slots and Teflon transport tubes to the inside flume wall for this purpose.

Rainfall events often occur at night or on weekends and the difficulty (and cost) of maintaining around-the-clock surveillance is recognized. Local weather forecasts should be utilized to assure that field personnel are present during key periods, while minimizing the overall time commitment.

It is important that one experienced person be assigned overall responsibility of field operations including maintenance and operation of all field equipment, sample collection, and data compilation.

3.13 CANOPY DEVELOPMENT

Crop canopy development as related to the percent soil cover has an impact on detachment of soil fines and erosion during rainfall events. Estimates of canopy development can be obtained by taking photographs from a step ladder looking down onto the crop canopy as discussed by Johnson and Baker (1982). The resulting photograph can be placed over a grid to determine the percentage of soil area covered by crop canopy (Figure 3.41). Examples of canopy developments for corn and soybeans are provided in Table 3.10. Measurements of the percent of soil area covered by crop canopy are needed at regular intervals (weekly) throughout the crop growing season. One additional post-harvest measurement of residue coverage is also advisable.

3.13.1 Leaf Area Index

Leaf area index measurements taken at various times throughout the crop growing season are useful in estimating fraction of ground cover, potential evapotranspiration, mass of pesticide on foliage at application, washoff and uptake per unit leaf area. Carsel et al. (1984) used leaf area index measurements to estimate ground coverage as follows.

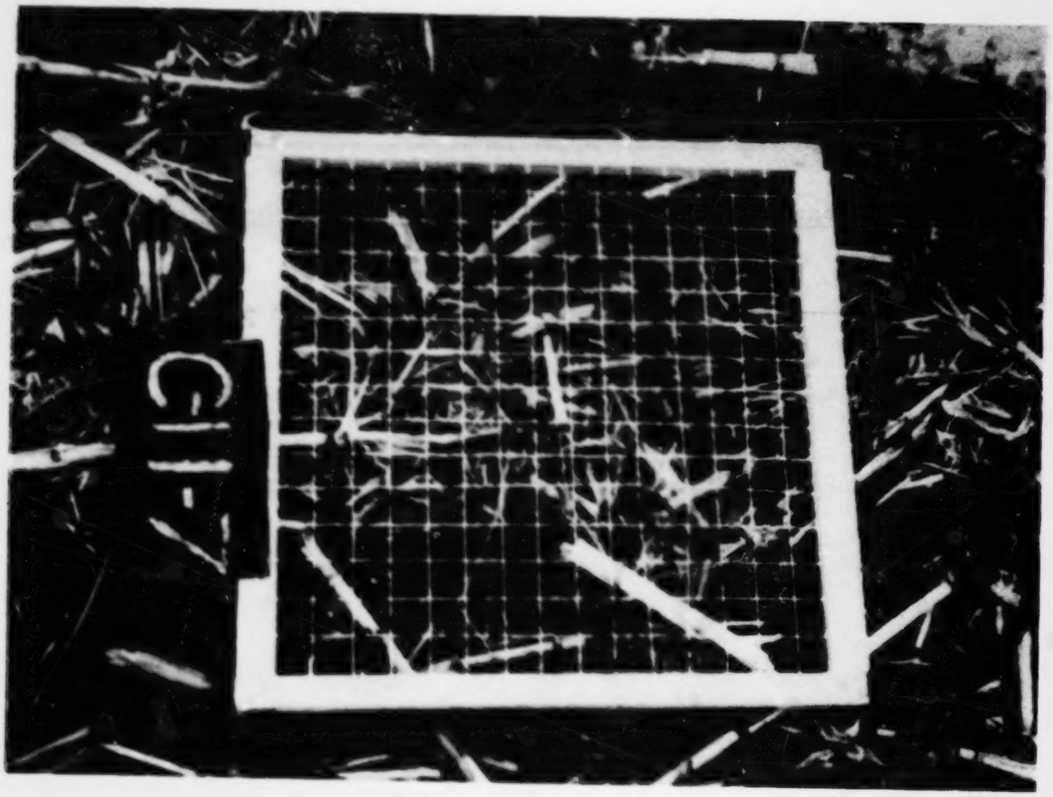


FIGURE 3.41. Grid for crop residue determination.

$$COVMAX = (2.0 - ERFC\ (1.33\ LAI_{\ell,m} - 2.))/2.1$$

where COVMAX = fraction of ground covered by the plant

LAI = leaf area index of crop, m, on day, ℓ

ERFC = complimentary error function

Measurements of leaf area index should be taken at weekly intervals during the crop growing season until harvest. A representative number of plants (i.e., 20 to 30) should be utilized to obtain a representative field average value. Both portable and laboratory area meters are available. The portable area meters provide a means of monitoring of crop canopy development without leaf destruction. If leaves are collected from the field, measurements must be made before they shrink or curl.

TABLE 3.10. CROP LEAF CANOPY DEVELOPMENT
(Johnson and Baker 1982)

Date in 1978	Pencentage of Soil Surface Area Covered by Crop Leaf Canopy	
	Soybeans	Corn
5/23	0	1
5/31	3	4
6/7	6	14
6/14	12	23
6/21	19	37
6/29	35	67
7/7	49	88
7/13	63	91
7/24	86	95
8/1	94	98
8/14	85	--
9/19	97	--
9/21	--*	85
10/3	93	--
10/31	--	95*

*After harvest.

3.13.2 Foliar Washoff

Once a pesticide is applied and intercepted by plant foliage, it may undergo several processes, including sorption, volatilization, degradation, and washoff. After washoff occurs, the residue will either accumulate in the soil or contribute to runoff.

A pesticide foliar washoff model was recently developed and evaluated by Smith and Carsel (1984). This model provides an empirical simulation of pesticide washoff from plant leaf surfaces as influenced by rainfall amount. Daily rainfall amounts (cm day^{-1}) are required, along with a lumped first order degradation rate constant (k_f) for foliar transformation processes.

Foliar washoff can be monitored using collection vessels placed under the canopy to intercept washoff and dislodgeable residue (Smith et al., 1981; McDowell et al., 1984). Measurement sensitivity can be increased substantially by using large area funnels to feed the collection vessels. The number of collection vessels and their locations must be determined to obtain the required random sampling and precision for estimating the amount of washoff. Experimental design should follow rules similar to those discussed in Section 3.7.4. Optimum sizes of collection vessel openings are difficult to specify. Generally, larger vessels yield more representative samples. Each vessel location should be identified (i.e., wooden stakes) to eliminate possible data discrepancies that might occur if vessels were inadventently relocated after servicing (Smith et al., 1981).

In an orchard, the collection vessels should be located within the tree drip lines. Locations within tree lines should be chosen randomly from among a number of locations that are predetermined on the basis of some sort of grid pattern. The general idea is to ensure random sampling of the under-canopy locations. In some cases, stem flow may be important and will require monitoring. Typically, a tight fitting annular ring around the trunk is used to collect flow, with a tube outlet for sample collection. The trees actually used can be selected randomly from all that are available. Usually it will be best to utilize as many trees as possible rather than choosing a few trees and sampling more heavily under each. The objective generally will be to obtain a precise estimate of the mean amount per container per event.

Samples should be collected immediately following a rainfall/washoff event to reduce potential attentuation losses (i.e., volatilization, etc.). Once washoff occurs, the solution volume in collection vessels should be measured and recorded. Samples should be packed in ice coolers for transport to the analytical laboratory for analysis. To determine the amount of washoff from the whole field, the area of the field must be considered with regard to the area of the collecting vessels.

Random plant samples (whole plants preferred) or leaf samples (for trees) are required to establish mass balance and degradation rates. Foliage should be sampled before and after each pesticide application and again after each rainfall event. Overall losses reflected in these measurements will include degradation losses.

Foliar degradation rates (losses) must be evaluated through an additional sampling time series performed entirely within a rainless period. This series should include a minimum of three consecutive sampling dates and should preferably traverse at least one half-life.

3.13.3 Canopy Temperature

Canopy temperature affects degradation rates and volatilization losses of foliar applied pesticides. Measurements should be made at short time intervals until a diurnal cycle is established. Measurement schedules can then be optimized in accordance with model data needs. Several devices are commercially available for measuring surface temperature, Omega Engineering (1983).

3.13.4 Plant Uptake of Pesticides

The uptake of pesticides by plants is influenced by the mass and volume of the crop root system, physical and chemical properties of the soil matrix, plant metabolism and the pesticide. Uptake can be visualized as occurring in two steps: (1) absorption by the root system and (2) translocation into the above ground plant parts. Some pesticides do not absorb well and/or translocate significantly. In these cases, the pesticide effectively remains in the soil zone and is potentially available for runoff. The influence of uptake processes on pesticide runoff is variable. The effort expended in evaluating uptake should be in proportion to the expected impact on runoff losses. Recycling of pesticide through washoff and release from crop residues should be considered in this decision. Carsel et al. (1984) report <1.0 to 20% of applied pesticide can be removed by plant uptake.

If uptake is deemed important, a sufficient number (see Section 3) of random whole plant tissue samples should be collected to establish mass balance. Sampling times should correspond to soil sampling dates. Additional measurements may be required if it is desired that the uptake process itself be studied and evaluated.

3.13.5 Crop Yield

The average yield of the crop at harvest should be determined and reported. Yield measurements are determined by obtaining the total weight of the crop produced (e.g., kg, M_t etc.) and dividing by the harvested acreage. These determinations would typically be expressed as kg ha^{-1} and M_t ha^{-1}. The average yield of some selected crops were presented in Table 3.9. Commercial harvesting equipment is usually required for yield determinations on areas of several acres or more. Conventional harvesting machinery such as grain combines, cotton pickers, forage harvesters or other equipment should be used as appropriate. Average grain moisture content should be determined for converting total crop weight to a standard basis.

3.13.6 Pesticide Remaining in the Harvested Crop and Post Harvest Crop Residues

Crop residues left on the soil after harvest provide a protective layer that reduces erosion and soil runoff losses during the off season. A measure of the percent of surface coverage by post-harvest residue is required (see Figure 3.41). This can be determined photographically as noted in Section 3.13. These crop residues may contain pesticide residue which could serve as a source term at harvest time. To close the mass balance at the end of the cropping season, residue samples should be analyzed for pesticide content in both the harvested crop and post harvest crop residue.

3.14 VOLATILIZATION FROM SOIL AND PLANTS

Volatilization may be an important mechanism for removal of some pesticides applied to either soil or plant foliage. Pesticide loss due to volatilization will effect both mass balance and degradation rates.

If volatilization is deemed important, measurements should be obtained to establish mass balance. Measurements should be made frequently after application. The number of measurements will largely be determined by both pesticide properties and the occurrence of rainfall events after application. Examples of measuring volatilization losses were provided by Harper et al., 1976 and White et al., 1977 for soil; and Harper et al., 1983 and Willis et al., 1983 for plants.

Other studies have been conducted comparing herbicide volatilization losses under conservation and conventional tillage practices, Harper and Bush (1985).

3.15 MASS OF PESTICIDE IN PRECIPITATION

If atmospheric fallout of pesticides due to volatilization and drift is of concern, then the observer should consider obtaining samples of precipitation. Instrumentation is available for collecting a composite sample of precipitation for analysis. An example of a rainfall sampler was shown in Figure 3.18. Fallout is usually not a major concern in runoff studies.

3.16 TRANSPORTING SAMPLES

Soil samples taken from the field in ice coolers can be frozen and stored for analytical processing. If the samples are to be shipped to a analytical laboratory, it is important to freeze the samples to minimize degradation. For shipment, the samples should be packed in dry ice (if possible) and sent by air express to minimize delivery time. Arrangements for sample pick up at the airport should be made with the designated laboratory.

A similar procedure is required for shipping runoff samples. If the samples can be received at the analytical laboratory within 1-day travel time, refrigeration for a short time prior to shipment is adequate; the samples are then packed in ice for transport.

3.17 FIELD OPERATIONS RECORD KEEPING

Daily record keeping of field notes for various activities is an important task for the field operations manager. These records provide key data when conducting runoff model application studies. An example of field record keeping is shown in Figure 3.42.

3.18 ANALYTICAL METHODOLOGY

Specific pesticide analysis methods with sensitivities in the low parts per billion range are usually required for runoff testing. Modifications for extracting various media (filter discs, soil, runoff water and sediments and plant tissues) also should be developed. "Production line" analysis is necessary to provide a large sample throughput in a minimum amount of time. Analysis for pesticide residue is commonly done by gas chromatography or high pressure liquid chromatography. Various quality control activities should be planned in the analysis schedule as discussed in Section 4.

To minimize the effects of systematic bias attributable to laboratory procedural techniques and to ensure objectivity in the associated measurements, the samples generally should be analyzed in random order. Unless randomization is employed, any trends that arise cannot confidently be attributed to actual field phenomena or laboratory effects.

Detailed discussions of pesticide analysis methods are beyond the scope of this manual because they will vary with the pesticide. Analytical methods on some pesticides, however, have been developed by EPA's Environmental monitoring and Support Laboratory, Cincinnati, OH. Other excellent sources of references include U.S. EPA (1980), U.S. EPA (1983) and the Food and Drug Administration Pesticide Analytical Manuals, Vol. I (1985) and II (1984).

Soil core samples are analyzed for pesticide residue on a dry weight basis. Soil moisture content will vary from sample to sample and with sampling date and depth. Separate soil moisture content determinations are required for converting analytical data to a dry weight basis. A

Date	Description
1984	
Oct. 9	Location of field site and agreement established with land owner.
Oct. 20	Soil series identified by USDA-SCS personnel.
Oct. 25	Selected sampling sites identified.
Nov. 7	Installation of flume.
Nov. 15	Lime applied to site (2240 kg ha^{-1}).
Dec. 20	Installation of weather station completed, including two raingages, evaporation pan, instrument shelter (housing maximum-minimum therometers), relative humidity, solar radiation, and wind sensors.
Dec. 23	Fence constructed around weather station.
1985	
Jan. 1	Installation of water stage recorders and automatic sampler.
Mar. 1	Soil samples taken from each designated sampling area for background residue analysis at depths of 0-1, 1-7.5, 7.5-15, 15-30 cm.
Apr. 15	Fertilizer broadcast applied at site (rate of N (38), P (33), K (127), in kg ha^{-1}) and disk incorporated.
Apr. 29	Field site disk harrowed in preparation for planting. - Crop planted - seed information and planting rate (kg ha^{-1}) - Herbicide applied--target rate (3.36 kg ha^{-1} active ingredient) - Method of application and equipment--surface or incorporated - Application monitoring technique (i.e., filter disc size, location and number)
May 15	Soil samples taken after runoff event from each sampling segment at depths of 0-1, 1-7.5, 7.5-15, 15-30 cm.
Jun. 15	Soil samples taken (same as May 15).
Aug. 1	Full crop canopy established.
Sept. 1	Crop harvested. Crop grain yield data (5400 kg ha^{-1}); Stover (6800 kg ha^{-1}).
Sept. 15	Post-harvest treatment (i.e., stalks mowed and/or winter cover crop planted).

FIGURE 3.42. Typical record keeping of field operations.

subsample for soil water determination should be taken at the time a subsample is taken for pesticide residue analysis. This eliminates the need to dry the sample to be used for pesticide analysis. The drying process may cause pesticide loss or degradation.

Water content is expressed as a percent of the oven dry weight of soil:

$$\text{Percent moisture by weight} = \frac{\text{Wet soil weight - oven dry soil weight}}{\text{Oven dry soil weight}} \times 100$$

3.19 RUNOFF AND SOIL CORE DATA COMPUTATION

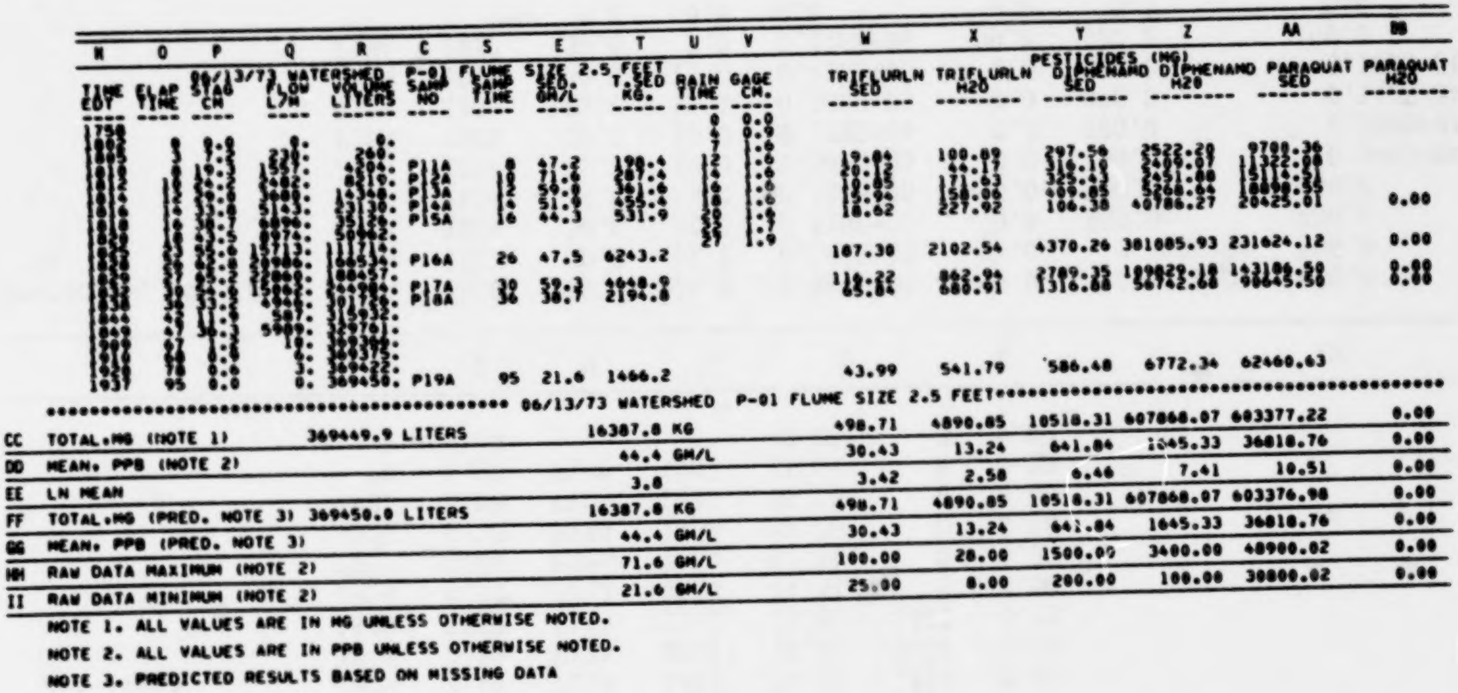
Runoff samples are collected during small but finite time intervals during individual runoff events. Each sample represents the average behavior within a particular time segment. Several computational steps are required in computing overall pesticide losses and evaluating dynamic aspects of the event. The mass of data involved usually dictates the use of some form of automated data processing equipment and software. A general discussion concerning development of a computerized data base is presented in Section 5. Figures 3.43 through 3.48 give example data tabulations and calculations. These include:

- Figure 3.43 - raw field and pesticide analytical data (see Figure 3.45 for column heading key)
- Figure 3.44 - runoff event summary (see Figure 3.45 for column heading key)
- Figure 3.45 - column heading key for runoff data computations
- Figure 3.46 - annual pesticide runoff summary
- Figure 3.47 - soil core data computations
- Figure 3.48 - pesticide residue summary

Input Data (Column)	A	B	C	D	E	F	G
Runoff, 061373 P1	1802	0.00	P11A	1810	47.19	1758	0.00
2.5 1973	1829	2.14	P12A	1812	71.57	1805	0.62
	1844	0.39	P13A	1814	58.99	1820	0.65
	1849	1.19	P14A	1816	51.86	1825	0.75
	1909	0.04	P15A	1818	44.34	0	0.00
	1910	0.03	P16A	1828	47.51	0	0.00
	1920	0.02	P17A	1832	59.26	0	0.00
	1937	0.00	P18A	1838	38.68	0	0.00
	0	0.00	P19A	1937	21.65	0	0.00
	-1	0.00			0.00	0	0.00

	C	D	H	I	J	K	L	M
Pesticide, 061373	P11A	1810	100.0	24.0	0.489E+05	-99.0	0.150E+04	600.0
P1	P12A	1812	70.0	11.0	0.394E+05	-99.0	0.110E+04	600.0
	P13A	1814	30.0	28.0	0.418E+05	-99.0	900.0	400.0
	P14A	1816	35.0	18.0	0.415E+05	-99.0	900.0	600.0
	P15A	1818	35.0	19.0	0.384E+05	0.0	200.0	0.340E+04
	P16A	1828	30.0	16.0	0.371E+05	0.0	700.0	0.290E+04
	P17A	1832	25.0	11.0	0.308E+05	0.0	600.0	0.140E+04
	P18A	1838	30.0	12.0	0.413E+05	0.0	600.0	0.100E+04
	P19A	1937	30.0	8.0	0.426E+05	-99.0	400.0	100.0
	-1		0.0	0.0	0.0	0.0	0.0	0.0

FIGURE 3.43. Example of raw field and pesticide analytical data from a runoff event (Smith et al., 1978).



```
   N     O     P       Q        R      C     S     E       T      U     V          W          X          Y          Z          AA         BB
                                                                                       PESTICIDES (MG)
       06/13/73 WATERSHED   P-01 FLUME SIZE 2.5 FEET
 TIME  ELAP  STAG   FLOW   VOLUME   SAMP  SAMP  SED.   T.SED  RAIN  GAGE   TRIFLURLN  TRIFLURLN  DIPHENAMD  DIPHENAMD  PARAQUAT   PARAQUAT
 EDT   TIME   CM    L/M    LITERS    NO   TIME  GM/L    KG.   TIME   CM.     SED        H2O        SED        H2O        SED        H2O
 ----  ----  ----  -----  -------   ----  ----  ----  -----   ----  ----  ---------  ---------  ---------  ---------  ---------  ---------
 1758                                                           0    0.0
 [illegible]                                                    4    0.9
                                                                7    1.6
                                    P11A    8   47.2   190.4   12    1.6      19.04     100.09     297.56    2522.20    9700.36
                                    P12A   10   71.6   287.4   14    1.6      20.12      44.17     316.10    2409.07   11322.08
                                    P13A   12   59.0   361.6   16    1.6      10.85     171.63     325.43    2451.80   [illegible]
                                    P14A   14   51.9   455.4   18    1.6      15.94     158.06     409.85    5268.64   18098.55
                                    P15A   16   44.3   531.9   20    1.6      18.62     227.92     106.38   40786.27   20425.01       0.00
                                                               22    1.6
                                                               25    1.7
                                                               27    1.9
                                    P16A   26   47.5  6243.2                 107.30    2102.54    4370.26  381085.93  231624.12       0.00
                                    P17A   30   59.3  4048.9                 116.22     862.94    2709.35  109829.18  143106.50       0.00
                                    P18A   36   38.7  2194.8                  65.84     680.91    1316.88   56742.68   98645.50       0.00
 [illegible]
             67          19.  [illegible]
             [illegible] 6.   369375.
             78          3.   369422.
 1937        95   0.0    0.   369450.  P19A   95   21.6  1466.2                  43.99     541.79     586.48    6772.34   62460.63
****************************************** 06/13/73 WATERSHED  P-01 FLUME SIZE 2.5 FEET*******************************************
CC  TOTAL.MG (NOTE 1)           369449.9 LITERS       16387.8 KG          498.71    4890.85   10518.31  607868.07  603377.22       0.00
DD  MEAN. PPB (NOTE 2)                                   44.4 GM/L          30.43      13.24     641.84    1645.33   36818.76       0.00
EE  LN MEAN                                               3.8                3.42       2.58       6.46       7.41      10.51       0.00
FF  TOTAL.MG (PRED. NOTE 3) 369450.0 LITERS           16387.8 KG          498.71    4890.85   10518.31  607868.07  603376.98       0.00
GG  MEAN. PPB (PRED. NOTE 3)                             44.4 GM/L          30.43      13.24     641.84    1645.33   36818.76       0.00
HH  RAW DATA MAXIMUM (NOTE 2)                            71.6 GM/L         100.00      28.00    1500.00    3400.00   48900.02       0.00
II  RAW DATA MINIMUM (NOTE 2)                            21.6 GM/L          25.00       8.00     200.00     100.00   30800.02       0.00
    NOTE 1. ALL VALUES ARE IN MG UNLESS OTHERWISE NOTED.
    NOTE 2. ALL VALUES ARE IN PPB UNLESS OTHERWISE NOTED.
    NOTE 3. PREDICTED RESULTS BASED ON MISSING DATA
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FIGURE 3.44. Example of a runoff event summary (Smith et al., 1978).

Column	Description
A	Time series of runoff (derived from breakpoint on water stage recorder).
B	Stage height (ft), corresponds to A's times.
C	Sample numbers.
D	Time sample was taken (obtained by mark on water stage recorder).
E	Amount of sediment in sample, g/l.
F	Time series of rainfall (breakpoint on rain chart).
G	Accumulated rainfall (in.) per time (F).
H	Concentration of trifluralin in sediment
I	Concentration of trifluralin in water
J	Concentration of paraquat in sediment
K	Concentration of paraquat in water
L	Concentration of diphenamid in sediment
M	Concentration of diphenamid in water
N	Time (EDT). Chronological time which signifies when rainfall began and any change resulting in a break in the event such as an increase in rainfall, sample being taken or an increase or decrease in the runoff stage height.
O	Elapsed time of runoff or stage height change.
P	Stage height in flume (cm).
Q	Flow rate through the flume. This value is determined by taking stage height in centimeters (column P) and converting it to feet. By using the rating tables for the type flumes found in Agricultural Handbook Number 224, one can determine the discharge in ft^3/sec.

FIGURE 3.45. Column heading key for runoff data computations (Smith et al., 1978).

Column **Description**

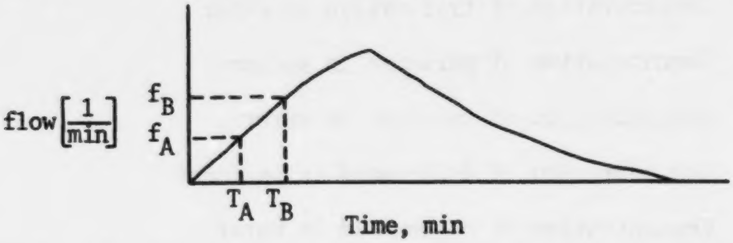
Example: stage height conversion factor ft^3/sec x 60 sec/min x 28.32 $liter/ft^3$ = flow (liter/min)

R Cumulative volume (liters). Volume is determined by approximate integration using the trapezoidal rule.

In the runoff event, each breakpoint on the water stage recorder represents a value for stage height and a corresponding value for time. These corresponding values enables one to compute flow from the flow versus stage height table. This, in turn, provides a plot of flow (liters/min) versus time (min). The flow versus time curve is then integrated by use of the trapezoidal rule to compute the approximate value for the area under the curve. The area under the curve is equal to the volume during the event.

The trapezoidal rule takes each corresponding flow value and time value and computes the area by the following equation:

AREA = ½(flow A + flow B) (Time B - Time A)



This value is the volume that has passed through the flume for the time period (T_B - T_A). This value, in turn, is added to the volume already accumulated. Each time increment is calculated and added to the accumulated volume until the event has ended.

Example:

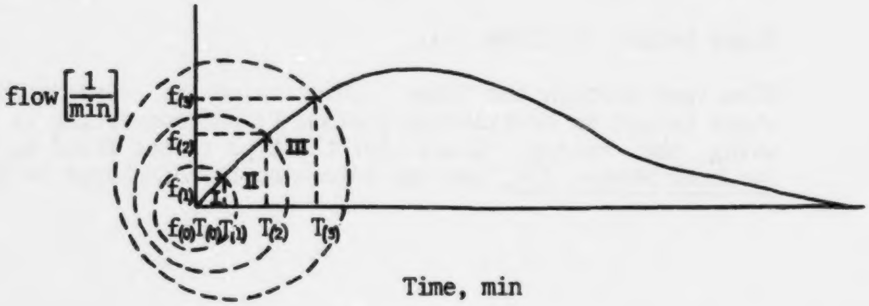


FIGURE 3.45 (Cont'd). Column heading key for runoff data computations (Smith et al., 1978).

Column	Description
	$\text{Volume I} = \frac{1}{2}(f_{(1)} + f_{(0)})\ (T_{(1)} - T_{(0)})$ $\text{Volume II} = \text{Volume I} + \frac{1}{2}(f_{(2)} + f_{(1)})\ (T_{(2)} - T_{(1)})$ $\text{Volume III} = \text{Volume II} + \frac{1}{2}(f_{(3)} + f_{(2)})\ (T_{(3)} - T_{(2)})$
S	Elapsed time after runoff began and when sample was taken.
T	Total sediment (kg) for the successive flow in column R (volume for corresponding sample - volume for previous sample) x column E x 0.001 kg/g = T. Total sediment (kg) = l x g/l x 1 kg/1000 g. Example: (8219 - 4204 liters) x 71.6 g/l x 0.001 kg/g = 287.4 kg. In cases where runoff continued without sampling, the volume of runoff is added to the last sample for computational purposes.
U	Elapsed time after rain began.
V	Accumulated rain gage values in cm.
W	Trifluralin in sediment, mg.
X	Trifluralin in water, mg.
Y	Diphenamid in sediment, mg.
Z	Diphenamid in water, mg.
AA	Paraquat in sediment, mg.
BB	Paraquat in water, mg.
	To calculate total mass of pesticide in the sediment, multiply total sediment (column T) by the concentration of the input data for that particular sample. Total (kg) x concentration (g/kg) x 0.001 mg/l = Total pesticide (mg)
	To calculate the total mass of pesticide in the water, multiply the volume (column R) for that particular sample by the concentration from input data for that sample. Volume (liters) x concentration (g/l) x 0.001 mg/l = Total pesticide (mg)

FIGURE 3.45 (Cont'd). Column heading key for runoff data computations (Smith et al., 1978).

Column	Description
CC	Totals: Runoff volumes (liters), sediments (kg), pesticides (mg).
DD	Mean values $= \frac{\text{Total sediment (kg)}}{\text{Total water (l)}} \times 1000 =$ g/l of sediment. $= \frac{\text{Total pesticide (mg) in sediment}}{\text{Total sediment (kg)}} \times 1000 =$ ppb pesticide in sediment $= \frac{\text{Total pesticide (mg) in water}}{\text{Total water (l)}} \times 1000 =$ ppb pesticide in water
EE	Ln (mean values).
FF	Predicted values based on missing data. These values are calculated from the samples taken before and after the sample following missing data. These two values are averaged to determine an average pesticide or nutrient concentration. This value is used for the concentration of the missing sample. The concentration is then multiplied by the amount of water, in liters, for the missing sample which will provide a value for total mass of pesticide in the water. If the pesticide sample is a sediment sample, an average concentration is determined and then multiplied times total sediment (kg) for the total mass in the sediment phase.
GG	Mean values for predicted values.
HH	Maximum values from input data (all values in ppb unless noted).
II	Minimum values from input data (all values in ppb unless noted).

FIGURE 3.45 (Cont'd). Column heading key for runoff data computations (Smith et al., 1978).

RUNOFF EVENT NO.	EVENT DATE	DAYS AFTER PLANTING	RAIN GAUGE (CM)	TOTAL RAINFALL (LITERS)	TOTAL RUNOFF (LITERS)	TOTAL SEDIMENT (KG)	RUNOFF %	MN. CONC. PESTICIDE IN SED. (PPB)	TOTAL PESTICIDE IN SED. (MG)	MN. CONC. PESTICIDE IN WATER (PPB)	TOTAL PESTICIDE IN WATER (MG)	TOTAL AMOUNT OF PESTICIDE (MG)	% OF SEASON TOTAL LOSS
1	05-23-74	24	6.88	968018.	26621.	18.3	2.75	568.2	10.4	324.5	8639.5	8649.9	81.0
2	06-27-74	59	5.33	750168.	89498.	90.2	11.9	197.3	17.8	6.8	609.6	627.4	5.88
3	06-27-74	59	3.30	464390.	221440.	345.8	47.7	224.0	77.5	5.4	1189.0	1266.5	11.9
4	07-27-74	89	7.65	1075184.	366917.	121.2	34.1	0.0	0.0	0.2	84.4	84.4	0.79
5	08-16-74	109	4.44	625140.	68908.	41.0	11.0	0.0	0.0	0.7	48.1	48.1	0.45
6	08-29-74	122	2.54	357223.	5024.	2.7	1.41						
7	12-15-74	230	3.18	446529.	674.	0.7	0.15						
8	12-19-74	234	2.16	303640.	491.	2.6	0.16						
9	12-29-74	244	2.29	321501.	7078.	5.2	2.20						
10	01-10-75	256	2.46	346534.	36758.	72.1	10.6						
11	01-12-75	258	3.12	439356.	112355.	114.0	25.6						
12	01-24-75	270	1.27	178612.	45262.	42.1	25.3						
13	02-04-75	281	0.0 *	0.*	71502.	33.5							
14	02-16-75	293	2.62	367911.	5429.	3.8	1.48						
15	02-16-75	293	1.52	214334.	12967.	9.5	6.05						
16	02-18-75	295	4.42	621624.	179207.	146.6	28.8						
17	02-24-75	301	2.41	339362.	69050.	51.8	20.3						
18	03-13-75	318	10.01	1407514.	769875.	434.2	54.7						
19	03-16-75	321	1.78	250056.	12630.	5.8	5.05						
20	03-18-75	323	2.82	396461.	95711.	30.7	24.1						
21	03-24-75	329	2.64	371568.	41617.	20.4	11.2						
TOTAL			72.85	10245123.	2239013.	1592.2	----	--------	105.7	-------	10570.6	10676.3	----

* ---- RAIN GAUGE STOPPED

FIGURE 3.46. Example of annual pesticide runoff summary (Smith et al., 1978).

The total mass of compound in a segment at a specific depth zone is calculated by the following:

$$\underset{\mu g/kg}{\text{Concentration}} \times \underset{m^2}{\text{Area of Segment}} \times \underset{g/cm^3}{\text{Bulk Density}} \times$$

$$\underset{cm}{\text{Height of Zone}} \times 1 \times 10^{-5} = \begin{array}{r}\text{Mass of compound in segment}\\ \text{per depth zone, g}\end{array}$$

After this calculation is performed, the mass of compound in each depth zone are summed for total grams of compounds. Then, the weighted mean concentration for each depth zone are computed.

$$\frac{\text{Total Mass on Watershed/Zone, g}}{\text{Bulk Density, g/cm}^3 \times \text{Height of Zone, cm} \times \begin{array}{c}\text{Total area of}\\ \text{Watershed, m}^2\end{array} \times 1 \times 10^{-5}} =$$

$$\text{Mean Concentration, } \mu g/kg \text{ (ppb)}$$

An example of the output data for each sampling interval are presented below:

Sampling Date: 07/10/73
Days After Planting: 25

Depth zones, cm	Segment number								Totals, g	µg/kg, ppb
	1	2	3	4	5	6	7	8		
0.0-1.0	11.3	9.2	18.1	23.0	6.1	20.9	0.7	0.2	89.6	444.0
1.0-2.5	6.8	20.7	16.9	41.4	12.2	37.6	0.2	0.1	136.0	449.6
2.5-5.0	5.6	9.8	33.9	46.0	10.2	41.8	0.5	0.1	147.9	293.4
5.0-7.5	2.3	2.9	11.3	5.8	0.5	4.7	0.4	0.0	27.8	55.1
7.5-15.0	1.7	3.5	1.7	3.5	1.5	3.1	0.0	0.0	15.0	9.9
15.0-22.5	-	-	-	-	-	-	-	-	-	-
22.5-30.0	-	-	-	-	-	-	-	-	-	-

FIGURE 3.47. Example of soil core data computations (Smith et al., 1978).

SAMPLING DATE / DAYS AFTER PLANTING

DEPTH ZONES IN CENTIMETERS	04-19-74	05-08-74	05-13-74	05-24-74	07-29-74
	-10	9	14	25	91
0.0 - 1.0	19.2	4246.7	4640.7	1805.4	98.3
1.0 - 2.5	25.2	1576.7	1465.7	1141.9	140.4
2.5 - 5.0	24.7	752.7	350.7	522.4	83.4
5.0 - 7.5	15.3	203.7	137.4	159.1	44.8
7.5 - 15.0	7.6	53.4	43.5	30.6	8.6
15.0 - 22.5	5.4	24.4	18.9	15.5	1.9
22.5 - 30.0	2.7	32.6	25.2	15.3	2.6

FIGURE 3.48. Example of pesticide residue summary, µg/kg (Smith et al., 1978).

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SECTION 4

QUALITY ASSURANCE PLANNING

Quality Assurance (QA) is an important consideration for all projects where measurements are made and in particularly in the case of environmental exposure assessments. The development of a QA project plan is an element that must be recognized prior to initiating any data collection efforts. The objective of a QA project plan is to ensure that the data are reliable and that they include measures of data quality (errors in the data are recognized, described and/or quantified) for all operational steps. Reference manuals relative to quality assurance that will be helpful includes Sherma (1981) and U.S. EPA (1979). A suggested prototype of QA planning elements is summarized below (EPA 1980).

1. Title Page.

2. Table of Contents.

3. Project Description.

    - State objectives of project and the intended use of acquired data.

    - State anticipated dates for starting and completing the project.

    - Site selection--discuss why the specific area and site was chosen as a representative area to evaluate runoff losses.

    - Experimental design--indicate how sampling sites are located within the field and include details of the statistical design.

4. Project organization and responsibility. List key personnel involved in the project and their major responsibilities.

5. QA objectives for measurement data in terms of accuracy, precision, completeness, representativeness, and comparability. Explain project objectives for each measured parameter listed in the project description in terms of precision, accuracy, completeness, representativeness, and comparability.

a. Accuracy. The degree of agreement of a measurement (or an average of measurements of the same thing), X, with an accepted reference or true value, T, usually expressed as the difference between the two values, X-T, or the difference as a percentage of the reference or true value, 100 (X-T)/T, and sometimes expressed as a ratio, X/T. Accuracy is a measure of the bias in a system. In many research projects accuracy is qualitative. In such cases there can be no statistical or numerical measure for accuracy, but the methods to be used for verification should be described in considerable detail.

b. Precision. A measure of mutual agreement among individual measurements of the same property, usually under prescribed similar conditions. Precision is best expressed in terms of the standard deviation. Various measures of precision exist depending upon the "prescribed similar conditions."

c. Completeness. A measure of the amount of valid data obtained from a measurement system compared to the amount that was expected to be obtained in the experimental design.

d. Representativeness. The degree to which data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition.

e. Comparability. The confidence with which one data set can be compared to another.

6. Sampling Procedures. If applicable, the following items must be considered whether the samples are environmental samples or synthetically prepared samples when comparable concentrations are a primary objective of the project. (In other cases, address as appropriate.)

a. special conditions for the preparation of sampling equipment and containers to avoid sample contamination

b. sample preservation techniques

c. reagent quality

d. sample preparation requirements

e. sample labelling procedures

f. sample transportation

g. collection of a representative sample

h. sample storage

7. Sample custody--indicate who will be responsible for sample handling at various stages (from collection to analysis).

8. Sample storage and recordkeeping--indicate how often samples will be taken, how many, sample number identification, sample containers, storage procedures in field, during shipment and in analytical laboratory.

    - discuss how all field and laboratory record data are kept

9. Calibration procedures and frequency--report procedures for all field monitoring equipment and laboratory analytical instrumentation utilized in the project.

    - frequency of calibration

    - calibration standards used

10. Analytical procedures--reference all appropriate standards or EPA-approved methods. Indicate proposed variances or other methods, where anticipated; reference same where possible and emphasize proper documentation of all procedures and techniques used in laboratory notebooks, etc.

11. Recovery structure--indicate the percent of samples that will be run to obtain recovery data for soil, plant, water and sediment.

12. Reagent QA--discuss the quality and source of standards, reagents, solvents, and gases for use.

13. Internal quality control checks and frequency--blanks will be prepared and analyzed; controls needed will be specified and analyzed.

    - split field sample analyses for all compounds being studied

14. Stability studies--discuss the collection and reporting results of representative samples during frozen storage with portions analyzed periodically (from representative sample taken shortly after application).

15. Data reduction, validation, and reporting.

    - data reduction--provide appropriate documentation and flow charting of computer programs used for statistical processing, logging, storage and retrieval

    - validation--transcribed data will be checked periodically for accuracy by checking raw data (sheets or logs) against transcribed data (tapes or printouts)

- reporting--data must be compiled on magnetic tape with appropriate documentation, compatible with most computer systems. Report data in standard units or as specified otherwise according to modeling requirements

16. Quality assurance reports--QA data should be included in reports submitted to EPA.

Functions that can be performed by both field and laboratory personnel to assist in an overall quality control program are (Plumb 1981):

Field Personnel

a. Providing a representative sample for analysis.

b. Providing replicate samples to define variation at a single point.

c. Providing a sufficient amount of sample to allow detection.

d. Spiking occasional samples to correct for sample decay between collection and analysis.

e. Initiating analysis or appropriate storage procedures immediately after collection.

f. Properly labeling and recording the dates and location of sample collection.

Laboratory Personnel

a. Using acceptable techniques for analysis.

b. Completing the analysis immediately (ideally) or within prescribed storage limits that are parameter specific.

c. Performing replicate analysis on approximately 5 to 10 percent of samples processed.

d. Adding standard solution spikes to approximately 5 to 10 percent of samples processed and determining recovery.

e. Using an internal laboratory standard to check performance of analytical method.

f. Analyzing externally prepared reference and performance (unknown) samples on a routine basis.

4.1 REFERENCES FOR SECTION 4

Plumb, R.H., Jr. 1981. Procedure for Handling and Chemical Analysis of Sediment and Water Samples. Prepared by Great Lakes Laboratory, State University College at Buffalo, Buffalo, NY, for the U.S. Environmental Protection Agency/Corps of Engineers Technical Committee on Criteria for Dredged and Fill Material. Published by the U.S. Army Engineer Waterways Experiment Station, CE, Vicksburg, MS. Technical Report EPA/CE-81-1.

Sherma, J. 1981. Manual of Analytical Quality Control for Pesticides and Related Compounds in Human and Environmental Samples. U.S. Environmental Protection Agency, Research Triangle Park, NC. EPA-600/2-81059, 455 p.

U.S. Environmental Protection Agency. 1979. Handbook for Analytical Quality Control in Water and Wastewater Laboratories. U.S. Environmental Protection Agency, Cincinnati, OH. EPA-600/4-79-019.

U.S. Environmental Protection Agency. 1980. Interim Guidelines and Specification for Preparing Quality Assurance Project Plans. U.S. Environmental Protection Agency, Office of Monitoring Systems and Quality Assurance, Washington, DC. QAMS-005/80.

SECTION 5

DATA BASE MANAGEMENT

5.1 INTRODUCTION

The purpose of this section is to describe the design, storage, manipulation, archiving, and documentation of a data base created on computer from data collected in a field program. The design of the data base should be considered at an early stage of the design of the data collection program. Some aspects of the field program can be affected by the data handling and data base management procedures. Many potential problems can be prevented by developing a proper design at an early stage in the planning.

The first item to be considered is the type of data to be put onto the computer. From this viewpoint, there are really two types of data:

- those that can be expressed purely numerically
- those that can be expressed only qualitatively

An obvious example of the former is a precipitation depth over a time interval at a location on a watershed. Depth, time, as well as location can all be expressed numerically. On the other hand a comment in a field notebook made at the time of this observation such as "tipping bucket mechanism was sticking and was lubricated" cannot be quantified.

It is clear that the observations of the first type should be computerized. The second type of information also can be entered as text into a word processing system or into files on the computer. Although this is time consuming and not essential, it does provide a back-up for information in field or laboratory notebooks that otherwise might be lost or destroyed.

In the final analysis, anything that can be written can be stored on a computer. It is probably a good idea to store all data, whether quantitative or qualitative in the data base. The remainder of this section, however, will deal only with numerical data.

The numerical data breakdown into two types:

- time series, and
- spatial (3-D) data.

An example of the former is, again, a precipitation time series at a single location on the watershed. An example of the latter are pesticide residue samples collected at several locations on the watershed at one time. Although it is not necessary, it is likely that these data types will be stored differently on the computer.

5.2 INTEGRATING THE FIELD DATA COLLECTION AND DATA MANAGEMENT DESIGNS

Each measurement taken in a field data collection program can be characterized by four attributes:

- type
- time
- location
- value

Each measurement that will yield a numerical value should be assigned a type identifier. These can be arbitrary but should be a string of four or less integers or alphanumeric characters. For instance, precipitation records might be identified by the type designation 'P' or '15' or 'R653'. If the data is to be entered into a comprehensive data base such as STORET, it may be useful to assign parameter codes that are used in the large data base. The only real requirement is that the identifier be unique.

When each measurement is taken it is essential that the time be recorded, that is, the year, month, day and in some cases the hour and minute of the measurement. The precision of time reporting depends on the relative dynamic nature of the quantity measured. For instance, minutes may be necessary to report during rainfall events; whereas the year, month and day may be sufficient for reporting percent crop canopy development.

The location of each measurement must also be reported. The location should be identified by an x-y-z grid coordinate in the data base. It may be easiest to mark a spatial location on a map and simply report the depth of a soil sample taken in the field. In the data base, however, the spatial location should be designated by an x-y-z coordinate. An appropriate datum for all location coordinates is the watershed outlet, which can be either specified as location (0, 0, 0) or (0, 0, MSL) in which MSL is the elevation of the gage above mean sea level. The x and y axes of the grid can be oriented conveniently; however, for consistency x due north and y due east are recommended. The plane of the horizontal should be normal to the direction of the force of gravity. A three dimensional grid of this type is shown in Figure 5.1.

In this figure, two locations A and B are shown. Location B is outside the watershed boundary and is a measurement made at the land surface. Its coordinates might be $x = 50$, $y = -25$ and $z = 6$ or $6 + MSL$

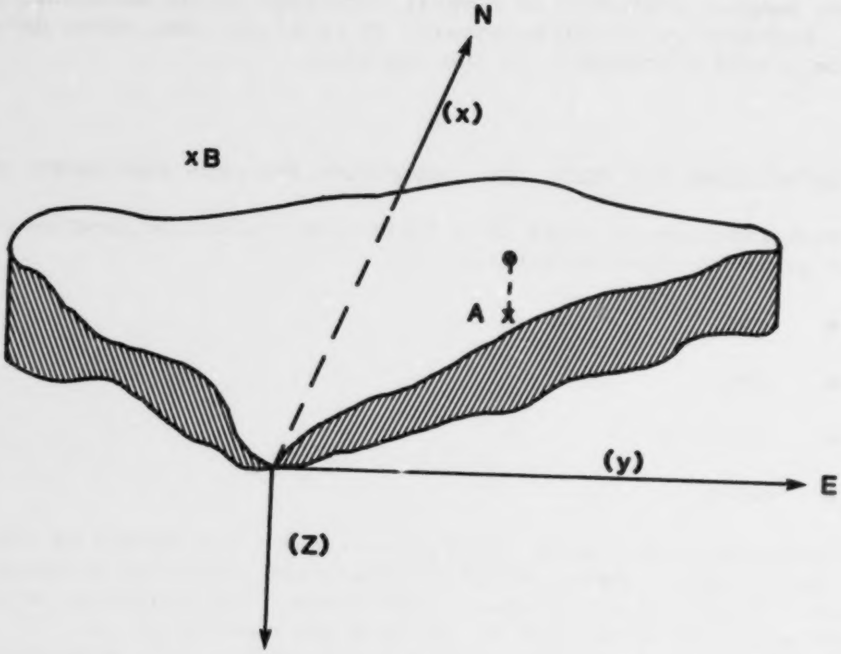

FIGURE 5.1. Use of a Cartesian Coordinate system to locate measurements in a watershed.

of the outlet. A is a location within the watershed. The measurement was taken beneath the land surface. Its coordinates might be x = 40, y = 10 and z = -2 or -2 + MSL of the gage. In this way any location in the watershed can be uniquely specified. A variation on this method would be to create a 3-dimensional grid, numbering each element within the grid. Grid numbers (e.g., x25, y14, z3) could be used to locate positions.

The last attribute of this measurement is its value. An example entry of a measurement in this data might be:

$$\underbrace{\text{SWC}}_{\text{type}}\underbrace{840630}_{\text{date}}\underbrace{1430}_{\text{military time}}\underbrace{25255}_{\text{x, y, z location}}\underbrace{0.43}_{\text{value}}$$

The advantage of entering data in this manner is that the data can easily be sorted by type, date or location in order to create files, hard copies, or plots of the information. The designer of the data base also may want to include columns for value units and for identifications of estimated values or other notes.

It is not necessary, and perhaps not desirable, to put every piece of data generated into one huge file. Large files are often difficult to use, especially on smaller computers. It may make more sense to group data according to type or function. For instance, one might put meteorological observations, watershed pesticide residue data, runoff and erosion data, and pesticide runoff data into separate files. Of course, these smaller files can always be generated from a master file containing all the data or vice versa.

Where several investigators are involved on the project, separate files for an individual's data may be desirable for proprietary purposes.

Record lengths should be kept to 80 characters. This will insure ease of downloading to microcomputers and obtaining hard copies from most printers.

5.3 DATA SECURITY AND TRACKING

A system should be established to keep track of the data from the time it is collected until it is stored permanently in final form in the data base. This will prevent the inadvertent loss of samples or information and provide a method for assessing the status of data reduction.

The individual responsible for collecting samples should record the date, time and location of the sampling. Any subsequent processing of the samples in the field should also be dated and initialed. When the samples are turned over to the laboratory for analysis, the collector should sign the samples over to the receiving authority. Any processing in the laboratory should also be dated and initialed.

The same type of security and tracking should be maintained during the reduction, entry and analysis of data. Raw data sheets from the collection or laboratory analysis phases should be signed over to the data management facility authority. Any subsequent data analysis steps should be dated and initialed upon completion. Archiving of important milestone levels of data reduction also should be recorded. Archiving will be covered later in this section.

A flow chart of the process of information reduction and storage should be produced. An example of this is shown in Figure 5.2. There may be several flow charts produced for different types of data. An up-to-date record of the status of the data process can be kept on the flow chart.

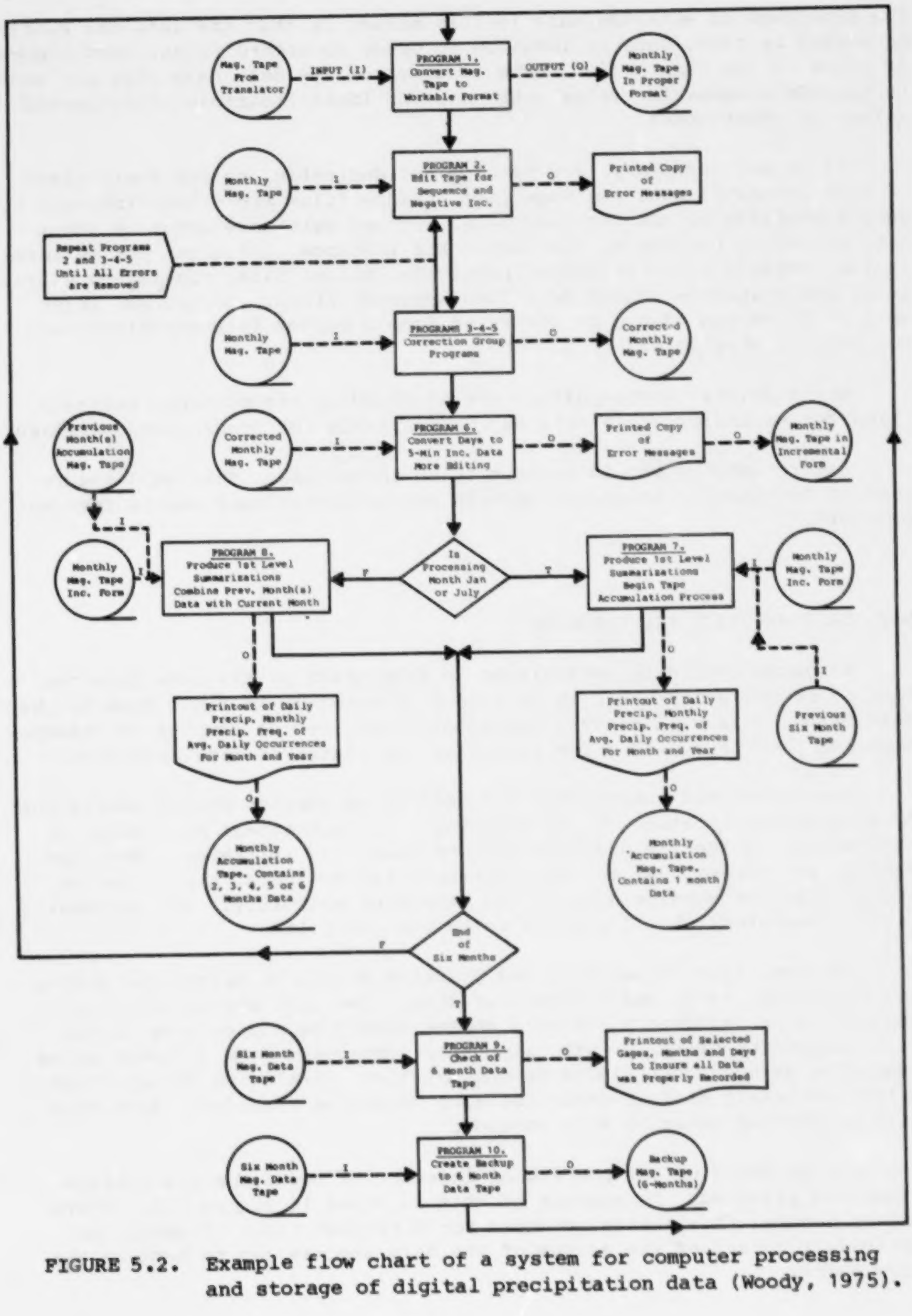
Mag. Tape From Translator
INPUT (I)
PROGRAM 1. Convert Mag. Tape to Workable Format
OUTPUT (O)
Monthly Mag. Tape In Proper Format
Monthly Mag. Tape
I
PROGRAM 2. Edit Tape for Sequence and Negative Inc.
O
Printed Copy of Error Messages
Repeat Programs 2 and 3-4-5 Until All Errors are Removed
Monthly Mag. Tape
I
PROGRAMS 3-4-5 Correction Group Programs
O
Corrected Monthly Mag. Tape
Previous Month(s) Accumulation Mag. Tape
Corrected Monthly Mag. Tape
I
PROGRAM 6. Convert Days to 5-Min Inc. Data More Editing
O
Printed Copy of Error Messages
O
Monthly Mag. Tape in Incremental Form
I
Monthly Mag. Tape Inc. Form
I
PROGRAM 8. Produce 1st Level Summarizations Combine Prev. Month(s) Data with Current Month
F
Is Processing Month Jan or July
T
PROGRAM 7. Produce 1st Level Summarizations Begin Tape Accumulation Process
I
Monthly Mag. Tape Inc. Form
O
O
I
Printout of Daily Precip. Monthly Precip. Freq. of Avg. Daily Occurrences For Month and Year
Printout of Daily Precip. Monthly Precip. Freq. of Avg. Daily Occurrences For Month and Year
Previous Six Month Tape
O
O
Monthly Accumulation Tape. Contains 2, 3, 4, 5 or 6 Months Data
Monthly Accumulation Mag. Tape. Contains 1 month Data
F
End of Six Months
T
Six Month Mag. Data Tape
I
PROGRAM 9. Check of 6 Month Data Tape
O
Printout of Selected Gages, Months and Days to Insure all Data was Properly Recorded
Six Month Mag. Data Tape
I
PROGRAM 10. Create Backup to 6 Month Data Tape
O
Backup Mag. Tape (6-Months)

FIGURE 5.2. Example flow chart of a system for computer processing and storage of digital precipitation data (Woody, 1975).

5.4 STORING DATA ON THE COMPUTER

There are three means of storing data on the computer, that is, there are three machine accessible media on which data can be stored:

- punched cards
- magnetic tape
- discs

There are advantages and disadvantages to each of these media. Punched cards have a long life and are unaffected by most environmental conditions except moisture. They are cumbersome, however, take up a lot of storage space, and need to be attended closely when being read by the machine. Punched cards are much less common presently than tape or disc. Magnetic tapes are also relatively long-lived but are more environmentally sensitive to heat, moisture, dust and magnetic fields. They require little room for storage and only moderate supervision when information is taken from them. Discs are sensitive to the same environmental conditions as magnetic tapes. They usually require more storage room than tapes but require almost no supervision when loaded onto or unloaded from the computer.

Whatever medium is used, data must be recorded to some level of accuracy (i.e., a certain number of significant digits). In the case of straight raw data transcription, the digits reported from the field or laboratory should be recorded. When changes are being made to raw data such as units conversions or multiplications by other data, only the number of digits of the least accurate data should be carried and recorded.

Most hydrologic data are only recorded to (at most) three or four significant digits; therefore, round off and truncation should not be a problem in manipulating these data on most machines.

5.5 DATA ENTRY VERIFICATION

Raw data that are entered on the the computer should be verified for correct transcription. The most accurate way of doing this is to transcribe small quantities of data at one time (20 to 30 values) and visually check each piece of datum entered. It is a mistake to enter all the data (say several thousand points) and try to verify them all at once.

Another useful way of checking or verifying entered data is to have the computer pick out the maximum and minimum values. Many times such a procedure will catch a misplaced decimal point or exponent. An equivalent way of doing this is to plot the data. Data should be rechecked from a hard copy once they are all entered. In this case, the output should be in a format similar to the raw data sheets for ease of checking.

5.6 DATA MANAGEMENT

Once the data are stored on the computer, the issues concerning the validity of the values should be considered. Adjustments may have been made to data between the field collection or laboratory analysis and data entry in the case of obvious errors. In some cases, however, analysis of the data values may be necessary to determine whether errors exist, and, if so, how to correct them. Two cases are considered in this section:

- the identification and correction of questionable data values
- the estimation of missing values

Questionable or missing values that are estimated should be so indicated in the data base.

5.7 QUESTIONABLE VALUES

Any measurement that is made has a certain amount of error associated with it. Measurement errors may be divided into two categories--systematic and random. A systematic error is one that occurs in the same direction each time a measurement is made thereby creating consistently high or low values. Examples are misalignment of a zero of a recording gage or an investigator who consistently reads an indicator high or low. Systematic errors are not necessarily of the same magnitude, even within the same experiment. For instance, a slowly changing temperature may cause an instrument zero to drift, introducing a trend or periodicity in the measurements. A sticking mechanism may cause periodic jumps in a series of measurements. These types of errors can be minimized by a number of means--proper training of personnel, proper service of instruments and good quality control.

Random errors, on the other hand, are caused by purely inexplicable phenomena and occur in no consistent direction, with no consistent magnitude. Examples are simple mistakes (misplacing a decimal point, transposition of digits) and variation caused by uncontrollable variables.

5.8 IDENTIFICATION OF SYSTEMATIC ERRORS

By far, the best way of determining the presence of systematic errors in a time series is to plot the data. Any trends, jumps and/or periodicities will normally be apparent from such a plot. If an error is suspected, the investigator will want to determine the cause, if possible. Field notebooks or interviews with data collection personnel could be helpful in this regard. In some cases, the trend or periodicity may be perfectly normal. In others it may be desirable to correct the data base by eliminating the error in the observed values.

5.8.1 Correction of Systematic Errors

Of the three types of errors listed above--trends, periodicities and jumps--the trend is probably the easiest to identify and correct. Essentially a regression of the values versus time is performed. The values can then be corrected by subtracting the predicted value of the regression from the observed value.

While linear trends are common (which would indicate a linear regression), this may not always be true. The appropriateness of the model to the observed trend should be assessed. In addition, the assumptions of the regression technique should be satisfied by the data set (see Section 6).

Correction of data for periodic effects follows the same principles as for trends, but requires the fitting of more intricate models. In this case a trigonometric function, such as the sine function may be appropriate and, for asymmetric periodicities, the Fourier series may be appropriate. The Fourier series representation of a parameter may be written as:

$$u(t) = \bar{u} + \sum_{j=1}^{m} A_j \cos (2 \pi jt/w) + B_j \sin (2 \pi jt/w), \quad (5.1)$$

$$t = 1,\ldots,w$$

where $\bar{u}$ = the mean of the series

j = the harmonics of the function

A and B = Fourier coefficients

Thus, it is easy to see that the value of 'u' at any time t can be approximated by the sum of a number of sine and cosine functions.

In general, by a jump we imply an abrupt change in the mean of the series of measurements as opposed to a trend in which the mean changes gradually. By evaluating the mean before and after the abrupt change occurs the questioned data can be corrected. The difference in the two means is simply added to or subtracted from the erroneous data, as required.

Computer programs used to perform regression or Fourier analysis are included in most standard statistical packages on larger machines.

5.9 IDENTIFICATION OF RANDOM ERRORS

Random errors can also be identified by plotting data and looking for extreme values or by running programs that identify maximum and minimum values in the data as was suggested in the section on data entry verification. Other statistical methods are also available, but unfortunately they are of limited practical use since statistics of the population (e.g., mean and standard deviation) must be known.

5.9.1 Correction of Random Errors

If a single value in the data is suspiciously higher or lower than related values, the best way to deal with it is to treat it as a missing value and use techniques of the following section to estimate a value.

5.10 MISSING VALUES

There are many reasons for the occurrence of missing values in a data set. Chief among them are equipment malfunctions, loss of sample, or improper analysis of a sample. It may not be necessary, or desirable, in all cases to estimate values for missing information. For the purposes of modeling it is usually necessary, however, to have complete unbroken records of the required time series inputs such as precipitation or pan evaporation. Therefore, we will focus on methods for filling in gaps in these types of records.

The method of filling a time series record depends largely on its structure. In this regard, there are two important types:

- intermittent
- continuous

An example of an intermittent series is precipitation. Precipitation may begin, last for a period of time, cease and begin again. This series is characterized by "events" that occur more or less at random. A continuous series is exemplified by a variable like temperature. A temperature reading can be made at any time. There is never a "no occurrence" value as there is in the case of rainfall. It is easy to see that there are some methods such as interpolation that may work well for a variable such as temperature, but would not work well for precipitation.

Several methods of estimating missing time series data are discussed in the following sections. These include:

- interpolation
- interstation correlation
- time series modeling

5.10.1 Interpolation

Interpolation can take on several functional forms. The most simple is linear interpolation. This method would be most likely utilized where there are a few missing data points in an otherwise intact record. Linear interpolation, in general, should only be used when the function being interpolated is smooth. The form of the linear interpolating function is:

$$y^* = y_1 + x^*-x_1 \frac{y_2 - y_1}{x_2 - x_1} \tag{5.2}$$

where y^* = interpolated value of the dependent variable.

x^* = value of the independent variable at which y^* is desired.

y_1 and y_2 = end point values of the dependent variable.

x_1 and x_2 = corresponding values of the independent variables.

Interpolation can also be accomplished with higher order polynomials. An example in the hydrologic literature is found in Mills and Snyder (1971). This is useful when there are more than a couple of missing data values together and a linear relationship is not adequate. A versatile and easily used method for finding an interpolating function of order 'n' where there are n + 1 data points is interpolation using Lagrange polynomials. It can be shown that if $f(x_i) = y_i$, $0<i<n$, then, $f(x)$ has a unique interpolating polynomial:

$$p(X) = \sum_{j=0}^{n} f(X_j)\ \ell_j\ (X) \tag{5.3}$$

The $f(x_i)$ are the values of y_i at corresponding values of x_i and the $\ell_j(x)$ (Lagrange Polynomials) are defined by:

$$\ell_j\ X = \prod_{\substack{i=0 \\ i\neq j}}^{n} \frac{(X-X_i)}{(X_j-X_i)} \tag{5.4}$$

The method is easily demonstrated with an example. Consider the time series of temperature in Figure 5.3. We wish to interpolate the values at days 4 and 5 using Lagrange polynomials. Thus at day 4 by equation 5.3:

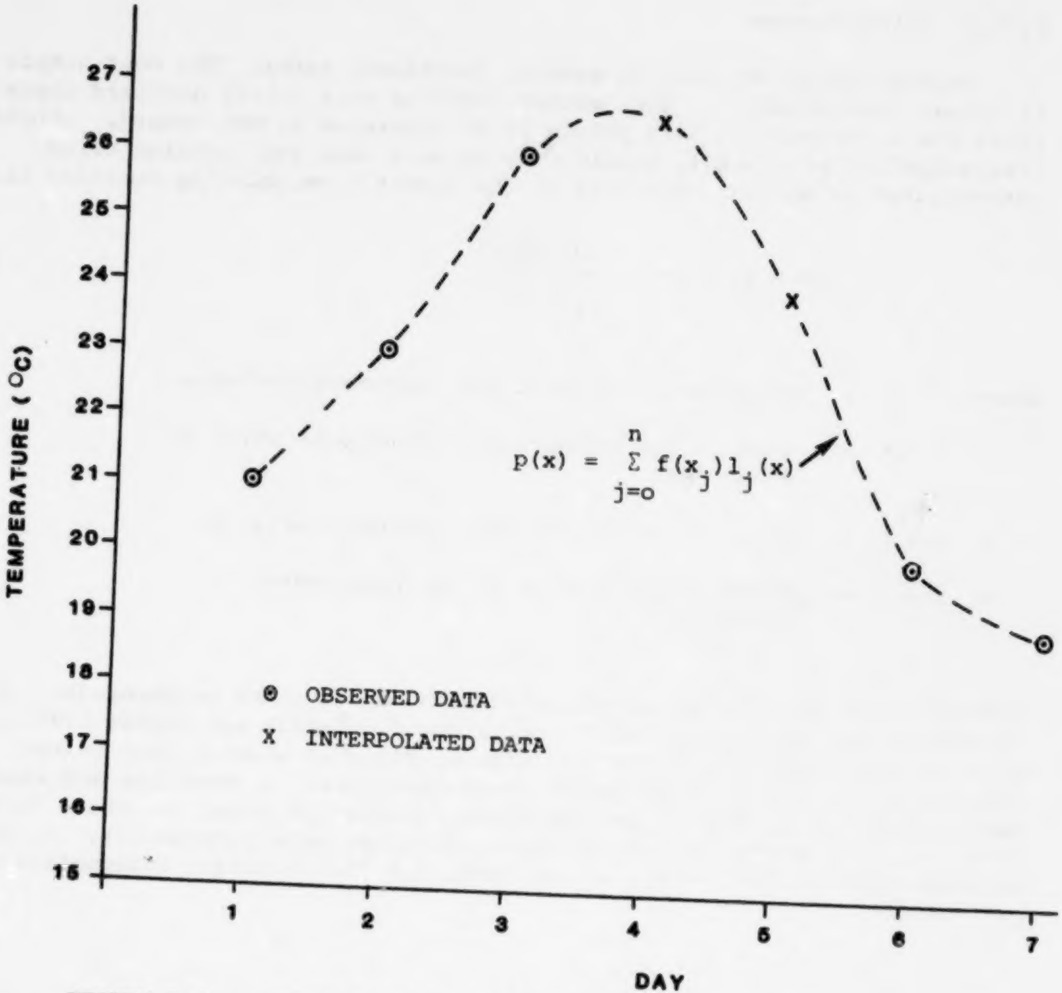

FIGURE 5.3. Interpolation of missing data using Lagrange polynomials.

$$P(4) = 21\ \ell_0(4) + 23\ \ell_1(4) + 26\ \ell_2(4) + 20\ \ell_3(4) + 19\ \ell_4(4)$$

Using Equation 5.4:

$$\ell_0(4) = \frac{(4-2)(4-3)\ (4-6)\ (4-7)}{(1-2)(1-3)\ (1-6)\ (1-7)} = 0.200$$

$$\ell_1(4) = \frac{(4-1)(4-3)\ (4-6)\ (4-7)}{(2-1)(2-3)\ (2-6)\ (2-7)} = 0.900$$

$$\ell_2(4) = \frac{(4-1)(4-2)\ (4-6)\ (4-7)}{(3-1)(3-2)\ (3-6)\ (3-7)} = 1.500$$

$$\ell_3(4) = \frac{(4-1)(4-2)\ (4-3)\ (4-7)}{(6-1)(6-2)\ (6-3)\ (6-7)} = 0.300$$

$$\ell_4(4) = \frac{(4-1)(4-2)\ (4-3)\ (4-6)}{(7-1)(7-2)\ (7-3)\ (7-6)} =- 0.100$$

Therefore

$$\begin{aligned} p(4) &= 21\ (0.20) + 23\ (-.90) + 26\ (1.5) \\ &\quad + 20\ (0.3) + 19\ (.1) \\ &= 26.60 \end{aligned}$$

Similarly $p(5) = 24.00$

The interpolating polynomial and the interpolated values $y(4)$ and $y(5)$ are also shown. The number of points used on either side of the missing data is arbitrary. The values of $\ell_j(x)$ decrease, however, as one moves away from the points being interpolated. Therefore the use of more than three or four points on each side will not improve the interpolated values appreciably.

Of course, there are other methods of interpolation. Fourier series can be used as well as spline functions. The above is, however, adequate for most applications where there are only a few missing points.

When performing interpolation a number of times, the above computational method becomes tedious. In this case, Aitkin's iterative interpolation technique can be used. It is easily programmed and the program is given in Figure 5.4. The user supplies the set of x and f(x), and the x at which an interpolated value of f(x) is desired. The subroutine returns the value of f(x) as PALPHA. This method of evaluating f(x) gives the same result as the above demonstrated method.

5.10.2 Interstation Correlation

Another useful technique for estimating missing data is by correlation with other records of the same variables from other stations in the vicinity. This technique is often used with rainfall, evaporation and streamflow records in various guises.

```
      SUBROUTINE AITINT(X,Y,ALPHA,PALPHA,N)
      DIMENSION X(20),Y(20),P(20),Q(20)
C
C  SUBROUTINE AITINT USES AITKEN'S ITERATED INTERPOLATION TO EVALUATE
C  THE INTERPOLATING POLYNOMIAL, P(X), AT A POINT X=ALPHA, WHERE
C  P(X(I))=Y(I), I=1,2,...,N.  THE CALLING PROGRAM MUST SUPPLY THE
C  ARRAYS X(I) AND Y(I), THE POINT ALPHA AND AN INTEGER N.  THE
C  SUBROUTINE RETURNS P(ALPHA) AS PALPHA.
C
      DO 1 K=1,N
    1 P(K)=Y(K)
      DO 3 J=2,N
      F=ALPHA-X(J-1)
      DO 2 K=J,N
    2 Q(K)=((ALPHA-X(K))*P(J-1)-F*P(K))/(X(J-1)-X(K))
      DO 3 K=J,N
    3 P(K)=Q(K)
      PALPHA=P(N)
      RETURN
      END
```

FIGURE 5.4. Computer subroutine for interpolation using Aitken's Iterated Interpolation (Johnson and Riess, 1977).

The simplest method is, again, a bivariate linear regression. In this case, the value at the gage A is regressed on the values measured for the same time period at gage B. The linear regression is then used to estimate missing values at A given a recorded value at B. This type of regression is subject to the same problems and assumptions as that demonstrated in Section 6. In general, however, it is a useful and widely used technique.

Better estimates can usually be made if multiple records are available on which to perform the regression. In this case, multivariate regression is used. That is, the values at A are regressed on the values at B and C, then estimates at A are made using recorded values at B and C. Multivariate regression programs are available in most statistics and applied mathematics packages for computers.

An extension of interstation correlation is the regression of the record having missing values on the record of a different variable with which there exists a cause and effect relationship. For instance, if pan evaporation records are missing they may be estimated using relationships with measured solar radiation and temperature, and so on. These relationships will often yield better predictions than interstation correlation. Of course, there is also the possibility that estimates can be made by combining these two techniques. For instance, pan evaporation might be estimated by making use of temperature, solar radiation and pan evaporation from another station. A number of possibilities arise in different situations. The last group of techniques mentioned use still another source of information for estimating missing values; the time series itself.

5.10.3 Time Series Modeling

Time series models can range from the very simple to the very complex. As with any of these techniques, volumes could be written. Only simple models are considered here, along with references for more complex techniques.

Time series of natural phenomena usually have very complicated structures. They are made up of various combinations of trends, periodicities and random components. Figure 5.5 shows an example. This daily temperature series shows a long term period of one year overlain by many shorter term periods induced by the passage of warm and cold fronts. There is obviously randomness superimposed on these periodicities.

The essence of time series modeling is to decompose the problem into its components by modeling each component (analysis phase) and then to generate a new statistically equivalent series by regenerating the series from the components (synthesis phase). Missing values can then be selected from the same period in the synthetic series.

Dean and Mulkey (1982) modeled a daily pan evaporation time series which had a structure very similar to the daily temperature series in Figure 5.5. The existence of the annual period is demonstrated by the presence of the peak in the autocorrelation function of the daily pan evaporation series (Figure 5.6). The annual periodic component was modeled. This was done by fitting a Fourier series to the mean daily values grouped by the month. The standard deviation of the daily values grouped by month was also determined. The original series was then standardized by subtracting the monthly means from each value and dividing the differences by the monthly standard deviations, as follows.

$$r_i = \frac{X_i - X_m}{S_m} \qquad m = 1,\ldots,12 \qquad (5.5)$$

where r_i = new series of standard normal residuals

X_i = observed daily value

X_m = mean daily value for month m

S_m = standard deviation of daily values for month m

The fact that the annual period is removed by this procedure is demonstrated by the autocorrelation function of the residuals which shows no period of 365 days (Figure 5.7). Some residual autocorrelation still remains due to the shorter period passage of fronts. The autocorrelation function of Figure 5.8, which is a "close up" of the first 12 lags of Figure 5.7, shows this. It also shows that this residual correlation can be effectively removed by using a one lag autoregressive model (Markov model). This

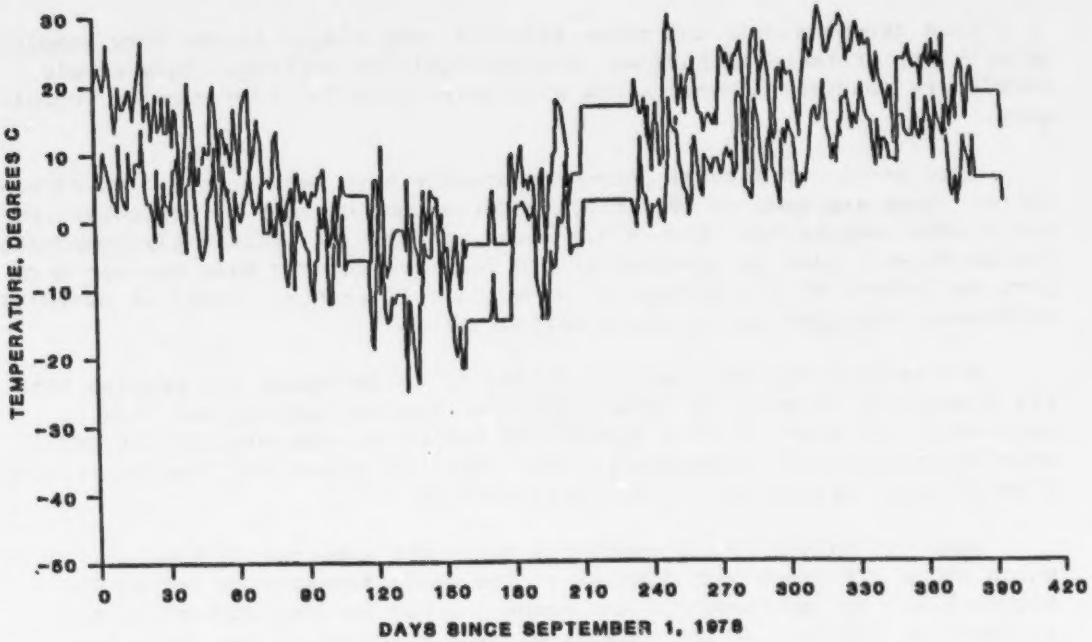

FIGURE 5.5. Minimum and maximum ambient air temperature at Panther Basin, September 1, 1978 to September 30, 1979. Flat sections of plots represent data gaps, Chen et al., 1982).

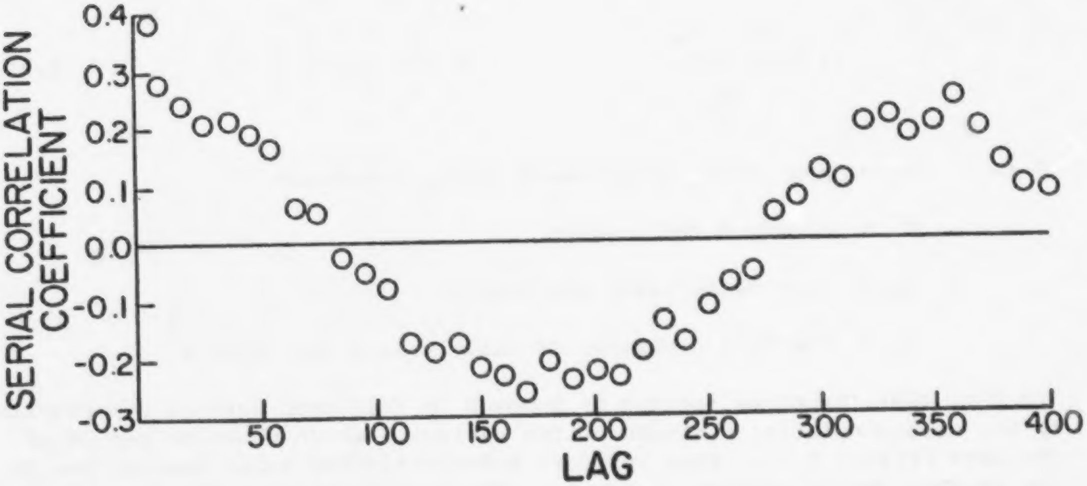

FIGURE 5.6. Autocorrelation function of daily pan evaporation.

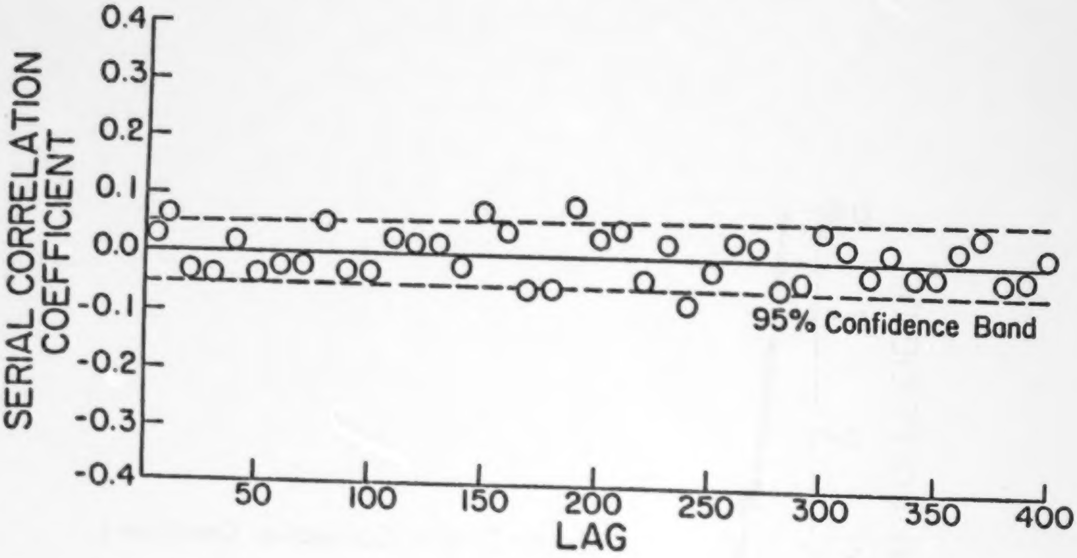

FIGURE 5.7. Autocorrelation function of standardized daily pan evaporation.

model simply states that the value of a pan evaporation residual depends only on the values of its immediate predecessor in time plus some error, or:

$$r_i = \emptyset r_{i-1} + \varepsilon_i \qquad (5.6)$$

where $\emptyset$ = value determined from auto regression

ε_i = error of the regression

The errors of the regression (ε_i) were shown to be normally distributed with a zero mean and unit variance, N(0,1) (see Section 6).

Thus a time series of pan evaporation statistically equivalent to the original series can be generated in three steps:

1) Select a normal random number with zero mean and unit variance (N(0,1)

2) Select a starting residual value and generate the next residual by using Equation 5.6:

$$r_i + 1 = \emptyset r_i + \varepsilon_i$$

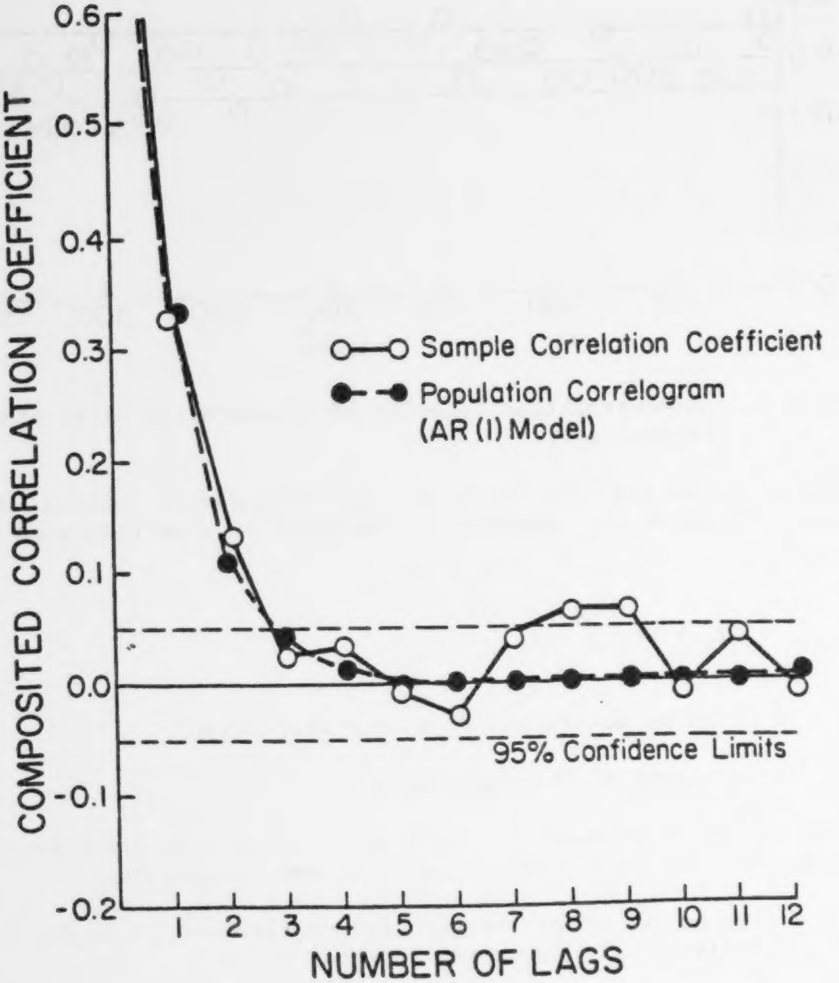

FIGURE 5.8. Enlargement of first 12 lags of autocorrelation function for standardized pan evaporation and fitted AR(1) model.

3) Generate a value of pan evaporation by destandardizing the residual using Equation 5.5:

$$X_{i+1} = r_{i+1} S_m + X_m$$

Of course, this is only one example of a relatively simple time series model. These types of models usually become more complex for shorter time intervals (e.g., hourly as opposed to monthly). Complications also arise for intermittent processes such as precipitation. For generation of short interval rainfall depths, "event-based" models may be used (e.g., Egbuniwe, 1975; Grace and Eagleson, 1966; Dean and Mulkey, 1982). For daily or longer intervals, Markov models are frequently used (e.g., Haan et al., 1976; Chin, 1977).

5.10.4 Summary of Techniques to Evaluate Missing Data

Three techniques, interpolation, regression, and time series modeling, have been advanced as possible methods for estimating missing values in time series data sets. For continuous variables (e.g., pan evaporation, temperature) where only a few data are sporadically missing, some form of interpolation will provide reasonable estimates. These methods are easy to use and require little data analysis. When longer periods of missing data exist, especially if the time series is intermittent, some form of interstation or cause-effect correlation, or time series modeling is preferred. The correlative methods usually require a little less work than statistical time series models and are more generally used. The method of estimation can also depend on the ultimate use of the data set. If the data set is to be used for model calibration or verification then regressive methods will give estimates closer to the actual values missing. Statistical time series models will not necessarily do this. They are particularly well-suited, however, for extrapolating records to be used as inputs to deterministic models for the pupose of performing frequency analyses of model outputs.

5.11 ARCHIVING THE DATA BASE

Archiving refers to the permanent storage and safekeeping of the data base. In general, milestone steps in the processing of the data should be archived. At least three stages stand out:

- original data (e.g., breakpoint rainfall)
- data that has been further reduced or converted (e.g., interval rainfall derived from breakpoint)
- data in which missing values have been estimated (i.e., model-ready rainfall input files)

Archiving at these major stages can save many hours of work if an error is found at a later date.

Archived data should be carefully stored. All canisters, boxes or other storage containers should be clearly labeled. Usually, tapes in a tape library are numbered. The numbering system should be stored both in the vicinity of the data storage facility and at an alternative location.

Tapes or discs should be stored in a clean environment. Temperatures should correspond to those comfortable for humans. No smoking, eating or drinking should be permitted in the storage area. Tapes and discs should be stored away from any sources of electromagnetic radiation. They should remain in their protective canisters when not in use. There should be at least one back-up copy of the complete data base stored at another location. Two copies are preferable.

Tapes should be rewound every year to relieve tension on certain parts of the tape surface. Information on tapes should be rearchived every 3-5 years to avoid possible deterioration of any kind.

5.12 DATA BASE DOCUMENTATION

The data base will be much more useful and usable if it is properly documented. The following items should be discussed in the documentation:

1) What is in the data base. This should contain a detailed discussion of the type of data stored, how it is grouped and, in the case of multiple discs or tape reels, which data reside on which discs or tapes.

2) How the data is stored and formatted. The documentation should contain the format statements with which the data were written to storage. Also included should be the key to data type, location and units of the values, in addition to the specifications for the tapes (e.g., EBCDIC, 1600 bpi, 9 track, etc.)

3) Estimated values. Any procedures that have been used to estimate questionable or missing values should be clearly documented. Also any procedures that have been used to reduce or convert data should be documented. If computer programs were used for these purposes, they should be identified in the documentation along with instructions for their usage. Flow charts showing the use of various programs and procedures should be included.

4) Supporting programs. Any programs that have been written to retrieve, output or plot data should be included for the convenience of users. Example outputs should be included.

5) Storage. A log should be kept indicating the last time tapes (or discs) were inspected, rewound, or rearchived.

6) Usage. An up-to-date list of the organizations or individuals to whom the data base has been sent should be maintained at all times.

Two examples of documentation of computerized hydrologic data bases can be found in Woody (1975) and Hibbert and Cunningham (1966).

5.13 REFERENCES FOR SECTION 5

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SECTION 6

DATA ANALYSIS AND MODELING

Information in this section provides a link between the finished data base and the actual use of the data base for calibrating and verifying models and time series simulations for performing exposure assessments. As such, it is divided into two sections--data analysis and model calibration and verification.

Data analysis, in this case, refers to preparation of data to be used in the model. Recall that checking or verifying such data and estimating missing values were covered in Section 5.

The section on model calibration and verification does not address the nuances of these problems for specific models, but rather discusses useful statistical methods by which simulated and observed data can be compared.

The subject of model verification or "model performance testing" is rather broad. In essence, any technique that serves to effect a relevant comparison between observed and model-predicted values can be useful and informative in this context. There are some simple statistical techniques that can be employed to objectively test how well two sets of values agree. The choice of methods used in a given situation ought to depend upon how well the methods in question test important aspects of comparison or highlight differences that are of real significance. The few statistical techniques discussed here should not be construed as exhaustive, but they are likely to be generally quite useful in this type of comparison.

6.1 DATA ANALYSIS

Because the idiosyncrasies of the data produced by specific field studies and models are manifold, discussion of data base analysis for the purposes of using individual models is impossible. This section will discuss problems generally encountered, however, and will deal with some specific analysis techniques in detail. Many of these problems can be avoided by consideration of models to be used or analyses to be performed in the design of the data collection plan.

As mentioned earlier in this manual there are three types of data that the field study provides:

- data to be used directly as model input (e.g., precipitation) for the purpose of running models
- data to be used indirectly as a means of estimating model parameters that are subsequently used as model inputs
- data to be used directly or indirectly for the purpose of calibrating and/or verifying models (e.g., runoff data)

The most common problem involving the preparation of data for use in models is conversion of units. A table of useful conversions can be found in Appendix A.

6.1.1 Model Inputs

Data required as inputs to models can be further subdivided into two groups:

- time series
- discrete spatial data

Time series usually include precipitation, pan evaporation, temperature, and/or incident solar radiation. Models normally require that these data be input on equal time intervals--for example, hourly, daily or monthly. A common problem is that these data may not have been measured at equal intervals. This is most likely to occur with precipitation when "breakpoint" values instead of "interval" values may have been reported. In this case, the data will have to be converted.

6.1.1.1 Conversion of breakpoint precipitation to interval data

A typical breakpoint precipitation record is shown in Table 6.1. The simplest way of converting breakpoint to interval data is by interpolation. This is demonstrated graphically in Figure 6.1 for the storm of 5 August, 1973, from Table 6.1. The cumulative rainfall is plotted versus time and the cumulative interval totals can be read from the graph. By differentiating the cumulative interval totals, the interval incremental amounts can be determined. Resulting 10-minute-interval data are shown in Table 6.2. Of course, for large amounts of data this process is more easily accomplished on the computer.

6.1.1.2 Disaggregation of precipitation depths

Another frequently encountered problem is that data are recorded on a longer timestep than is usable by the model. In this case, the longer timestep data must be disaggregated to form interval data on a shorter timestep. This process can be quite complicated if done rigorously because of the stochastic nature of the rainfall process. A technique for generating

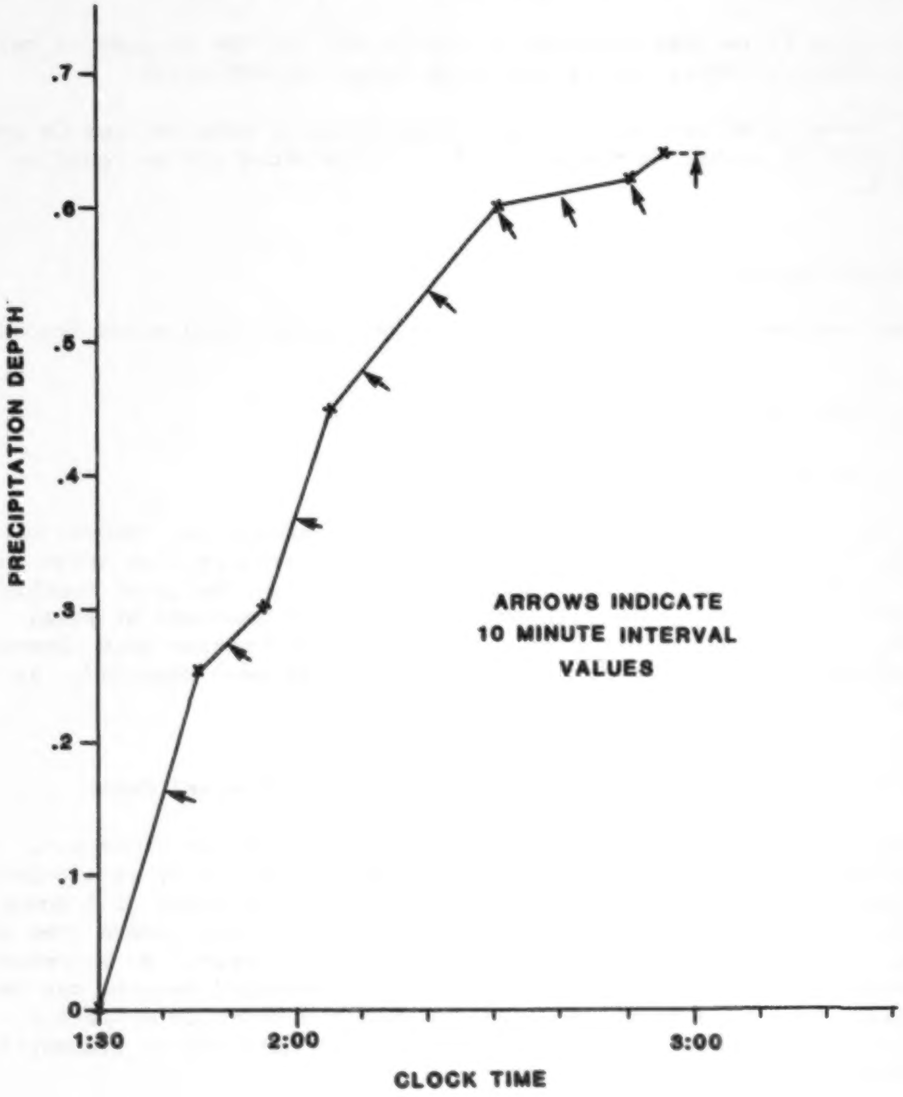


FIGURE 6.1. Cumulative plot of breakpoint storm rainfall from Table 6.1 (Precipitation depth in inches).

TABLE 6.1. HYPOTHETICAL BREAKPOINT PRECIPITATION RECORD

Date	Time	Time Interval (minutes)	Accumulated Depth (in)	Interval Depth (in)
2 Aug 73	8:20 a		0.0	
	8:45 a	25	0.2	0.2
	8:50 a	5	0.24	0.04
	9:10 a	20	0.38	0.14
	11:40 a	150	0.42	0.04
3 Aug 73	No Precipitation			
4 Aug 73	No Precipitation			
5 Aug 73	1:30 p		0.0	
	1:45 p	15	0.25	0.25
	1:55 p	10	0.30	0.05
	2:05 p	10	0.45	0.15
	2:30 p	25	0.60	0.15
	2:50 p	20	0.62	0.02
	2:55 p	5	0.64	0.02

TABLE 6.2. INTERVAL RAINFALL DATA DETERMINED FROM THE PLOT IN FIGURE 6.1

Time	Time Interval (minutes)	Accumulated Depth (in)	Interval Depth (in)
1:30	10	.0	
1:40	10	0.165	0.165
1:50	10	0.275	0.11
2:00	10	0.37	0.095
2:10	10	0.48	0.11
2:20	10	0.54	0.06
2:30	10	0.60	0.04
2:40	10	0.61	0.01
2:50	10	0.62	0.01
3:00	10	0.64	0.02

disaggregated time series is given by Valencia and Schaake (1973). Other stochastic disaggregation techniques have been discussed by Egbuniwe (1975), Grace and Eagleson (1966), Austin and Claborn (1971) and Dean and Mulkey (1982). Simpler techniques based on typical observed storm patterns (which ignores random effects) are discussed by Hjelmfelt (1980).

While the stochastic techniques are difficult to use and require substantial data analysis, the simpler techniques may be substantially in error for a given location. The best advice is to plan the acquisition of precipitation data on a timestep equal to the shortest timestep on which the model would be run. If a longer timestep is desired, the data can always be summed to give the proper interval.

6.1.1.3 Snowfall

In areas where snowfall is a substantial portion of precipitation during the winter, accurate snowmelt measurement are important in determining the annual water balance. It also may affect the antecedent moisture conditions in the soil at the time of spring pesticide application and runoff events.

Snowfall is normally measured by rain gages in the same manner as precipitation. The measurement of snowfall in precipitation gages, however, can underestimate total snowfall due to the effects of wind on the gage catch. One way of correcting the gage catch is to make snow course measurements on the watershed. If this has not been done, the snow catch of the gage can be adjusted if wind speed is known. The adjustment factor is shown in Figure 6.2 as a function of wind speed. These data sets were taken from Snow Hydrology (U.S. Army Corps of Engineers, 1956). The appropriate adjustment factor is chosen using the average wind speed occurring on the day of the snowfall. This factor is then multiplied by the water equivalent snow depth to estimate the actual snowfall in water equivalent.

6.1.1.4 Soil moisture

Soil moisture, as discussed in Section 3, can be determined by a variety of methods. Among these are gravimetric, soil tension, electrical resistance, and radiological methods. If gravimetric methods are used, the data will most likely be reported on a weight basis as a percentage. The formula is:

$$P_w = \frac{W_w - W_d}{W_d} (100) \qquad (6.1)$$

where P_w = percentage by weight of water in the soil

W_w = wet weight of the soil

W_d = dry weight of the soil

Usually, models require this measurement to be input on a volume basis instead of a weight basis. In this case, the weight basis percentage can be converted to the volume basis percentage by:

$$P_v = P_w \, \rho_s/\rho_w \qquad (6.2)$$

where P_v = volume basis percentage

P_w = weight basis percentage

ρ_s = bulk density of the soil

ρ_w = density of water

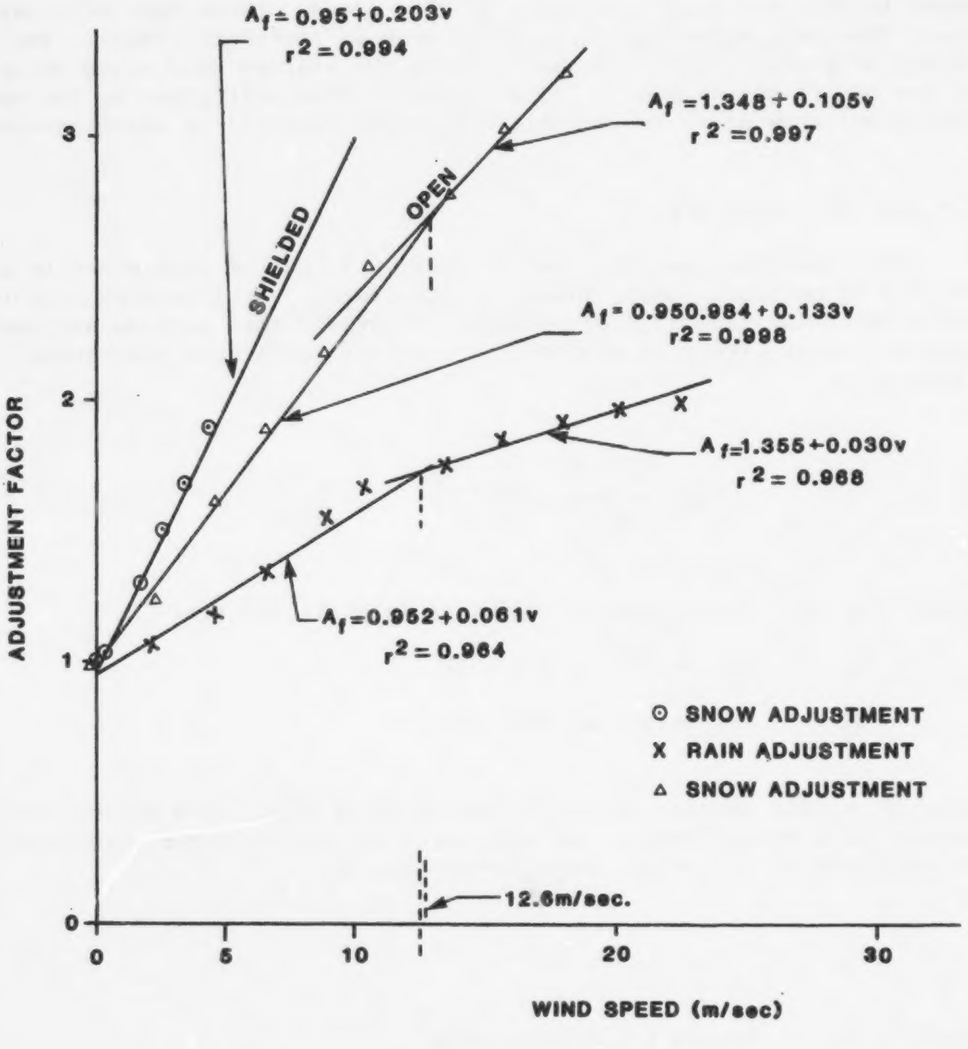


FIGURE 6.2. Adjustment factors for rain and snow based on wind speed (U.S. Army Corps of Engineers, 1956).

If the densities of water and bulk soil are expressed in g/cm^3, the value of ρ_w is conveniently equal to 1.

Soil tension, electrical resistance, and radiological methods have to be calibrated and the result can be expressed in weight or volume units as needed. Hillel (1980) contains a good discussion of soil water contents from the measurements produced by these various methods. In addition, the operator's manuals for these various instruments should contain adequate instructions.

6.1.1.5 Pesticide degradation rates

Most pesticide runoff models require that a first-order degradation rate of the chemical be entered. The field study should yield residue measurements at various times and depths in the soil. These measurements can be used to establish first-order degradation rates. It is important that, during the time period of the measurements utilized to establish degradation rates, no mass movement of the pesticide occurred by volatilization, leaching, runoff, or erosion from the soil zone. If mass movement does occur, the sum of pesticide residues in the entire profile may be used to estimate the degradation rate of the chemical because runoff losses are usually a small fraction of the total application.

Normally, volatilization can be lumped into the degradation process because runoff models do not usually account for this process separately. The same technique discussed below can be used for foliar degradation of a chemical, subject to one or two additional assumptions.

A typical set of pesticide residue measurements for the top centimeter of an agricultural soil are shown in Table 6.3.

The first-order degradation model is given by:

$$C(t) = C_o e^{-kt} \tag{6.3}$$

where $C(t)$ = concentration at any time t

C_o = initial concentration

k = first-order pesticide degradation coefficient

t = elapsed time

To determine k, the above model would be rearranged to solve for k. Thus:

$$L_n\ (C/C_o) = -kt \tag{6.4}$$

This indicates that a plot of ln (C/C_o) versus time should yield a straight line with a slope of -k. Figure 6.3 shows this plot. The computation of ln (C/C_o) is shown in Table 6.3. The k can be determined by a best-fit analysis of a staight line to the data points.

TABLE 6.3. PESTICIDE RESIDUE MEASUREMENTS IN THE TOP CENTIMETER OF AN AGRICULTURAL SOIL

Date	Intervening Elapsed Time (days)	Cumulative Elapsed Time (days)	Residue Level (ppb)	C/Co	ln (C/C_o)
5 April	(Appl. Date)		5.0	1.00	0.0
7 April	2	2	4.3	0.86	0.1508
10 April	3	5	4.0	0.80	- .2231
15 April	5	10	2.9	0.58	0.5447
30 April	15	25	1.4	0.28	-1.273

In some cases, a simple first-order model may be inadequate for describing the degradation process. The modeler, should select one of three options:

1. Assume a first-order model even though the fit of the data is not good
2. Investigate breaking the time after application into intervals during which single first-order decay models give adequate fits
3. Change to different models or model algorithms

6.1.1.6 Pesticide adsorption partition coefficient

The adsorption partition coefficient describes the distribution of pesticide between water and sediment phases. It is partly a function of soil properties and partly a function of chemical properties. For completely reversible, linear, instantaneous adsorption (a characteristic assumption of most runoff models) the coefficient is defined as:

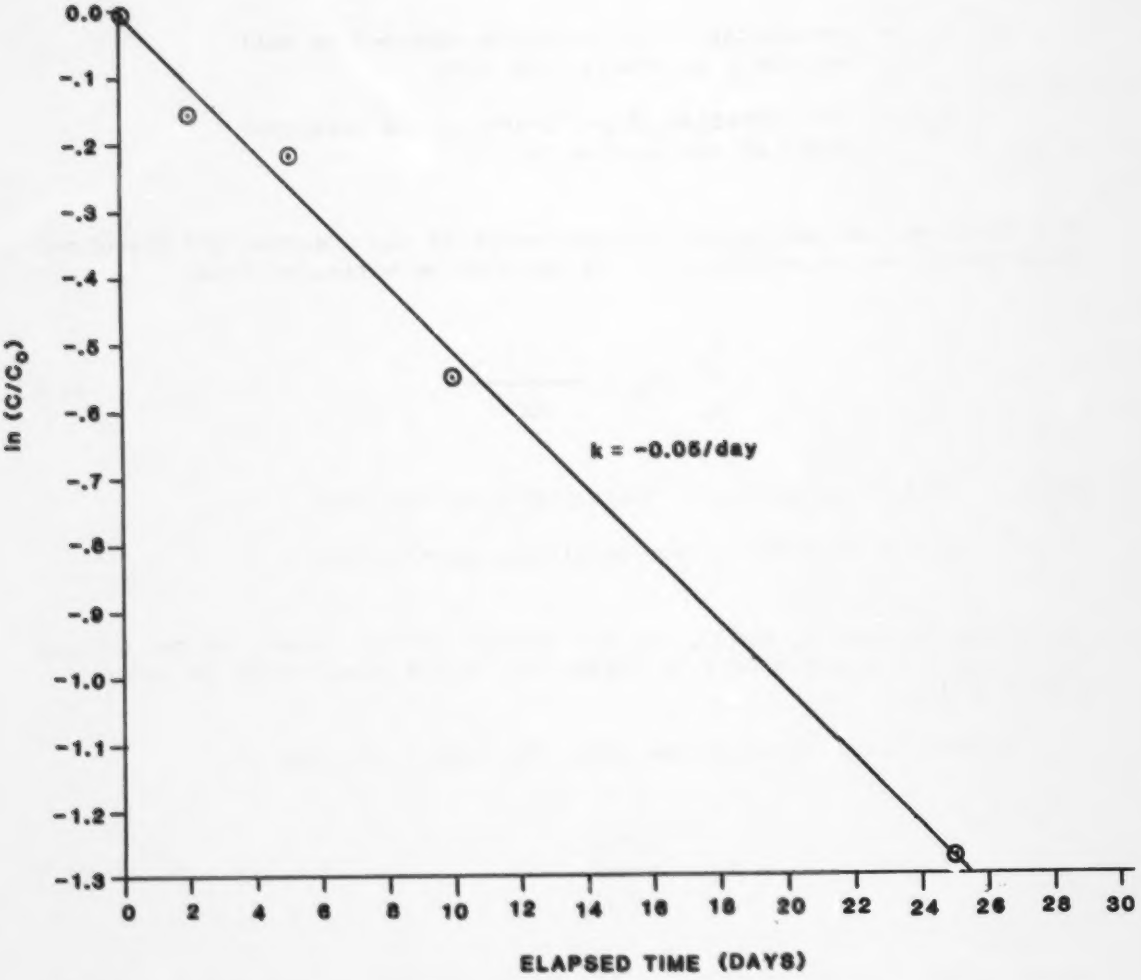


FIGURE 6.3. Graphical determination of a first-order pesticide decay rate.

$$K_p = \frac{C_s}{C_w} \qquad (6.5)$$

where K_p = adsorption partition coefficient (L^3/M)

C_s = concentration of pesticide adsorbed to soil materials at equilibrium (M/M)

C_w = concentration of pesticide in the dissolved phase at equilibrium (M/L^3)

This ratio can be determined by measurement of the adsorbed and dissolved phase pesticide concentrations. It can also be estimated from:

$$\frac{C_s}{C_w} = K_p = \frac{(OC)\ K_{oc}}{100} \qquad (6.6)$$

where (OC) = percent of organic carbon in the soil

K_{oc} = organic carbon partition coefficient

The concentrations C_s and C_w, or the organic carbon content of the surface and subsurface soils should be determined by the field study in order to determine K_p.

Another formulation of the partition coefficient is:

$$K_d = \frac{C_s - C_f}{C_w} \qquad (6.7)$$

where C_f = that portion of the pesticide that is permanently fixed to soil materials once applied

This formulation is used to account for pesticides that do not completely desorb once adsorption has occurred.

Other formulations take into account the non-linearity of the adsorption/desorption algorithm. One such formulation is the Freundlich equation:

$$K_f = C_s/C_w{}^{1/N} \qquad (6.8)$$

where K_f = Freundlich coefficient

N = Freundlich exponent

For $N = 1.0$, the Freundlich isotherm reduces to the simple linear isotherm. At low concentrations the assumption of linearity is often justified.

To evaluate the adsorption parameters required by these algorithms, the data can be plotted or regression analyses can be performed. In either case, "best fit" straight lines are estimated for the data.

Consider the adsorption data of Table 6.4. Regression analysis yields the information shown at the bottom of the table. The model $C_s = K_dC_w$ gives a K_d of 36.23, whereas, the model $C_s = C_f + K_dC_w$ gives a K_d of 35.99. Although these numbers are not very different, the effect of using the former model is to overestimate C_s at high C_w and underestimate C_s at low C_w. The Freundlich exponent $(1/N)$ of 0.9605 indicates that the relationship is close to being linear, as indicated by the good R^2 value of the linear model. The log K_f value indicates a K_f value of 46.23.

6.1.2 Model Outputs

For purposes of model calibration and verification (see Section 6.2) there are several model outputs that merit analysis. Model hydrologic calibration is achieved through the comparison of the flow rates and volumes. Fluxes, as well as concentrations, of sediment and pesticides are useful. Other statistical descriptions of the data also can be used.

6.1.2.1 Integration to produce volume and mass

Volumes of flow and mass fluxes of sediment or chemical constituents can be computed by integration of time series. The simplest case is flow. Figure 6.4 shows the hydrograph of a flow event, with $q(t)$, the instantaneous flow rate, plotted versus time. Flow (Q) is computed from:

$$Q = \int_0^t q(t)dt \qquad (6.9)$$

If $q(t)$ were a specific function the flow, Q could be found analytically. As it is not, this integration must be performed numerically. This is accomplished by approximating the function $q(t)$ with an interpolating polynomial and integrating the polynomial. The simplest ways of doing this are to use straight line segments and parabolic segments. This leads to the use of the trapezoidal rule and Simpson's rule. The trapezoidal rule is:

TABLE 6.4 ADSORPTION DATA FOR A PESTICIDE IN A SOIL-WATER SYSTEM

	C_w (ppb)	log C_w	C_s (ppb)	log C_s
Adsorption	0.0		0.0	
	1.0	0.0000	40.0	1.6021
	5.0	0.6990	185.0	2.2672
	10.0	1.0000	428.0	2.6314
	50.0	1.6990	1856.0	3.2686
	100.0	2.0000	3850.0	3.5855
	500.0	2.6990	18000.0	4.2553
Desorption	100.0	2.0000	3900.0	3.5911
	50.0	1.6990	1900.0	3.2788
	10.0	1.0000	500.0	2.6990
	5.0	0.6990	250.0	2.3979
	1.0	0.0000	50.0	1.6990
	0.0		35.0	1.5441

Model	Intercept	Slope	R^2
$C_s = K_d C_w$ (all data)	-	36.23[1]	-
$C_s = C_f + K_d C_w$ (all data)	80.56	35.99	0.9996
$\log C_s = \log K_f + \frac{1}{n} \log C_w$ (all data, except zeros)	1.6649	0.9605	0.9971

---

[1] $\text{Slope} = K_d = \frac{\Sigma(xy)}{\Sigma(x^2)} = \frac{\Sigma(C_s C_w)}{\Sigma(C_w^2)}$

$$Q = \int_o^t q(t)\, dt = \frac{\Delta t}{2} \left[q(o) + q(n) + 2 \sum_{j=1}^{n-1} q(j)\right] \qquad (6.10)$$

Simpson's rule, which is, in general, more accurate is given by:

$$Q = \int_o^t q(t)dt = \frac{\Delta t}{3} \left[q(0) + q(n) + 4\sum_{\substack{j=1 \\ j \text{ odd}}}^{n-1} q(j) + 2\sum_{\substack{j=2 \\ j \text{ even}}}^{n-2} q(j)\right] \qquad (6.11)$$

To use either of these formulae, the data must be divided into equally spaced intervals. This may entail deriving an equal interval hydrograph from a breakpoint hydrograph. Once this is accomplished, these integration formulae (or quadratures) are easily used. An example is shown in Figure 6.4. The volume derived (Q) is the area under the q(t) curve. When a constituent in the water is involved, the same integration procedure can be used to determine

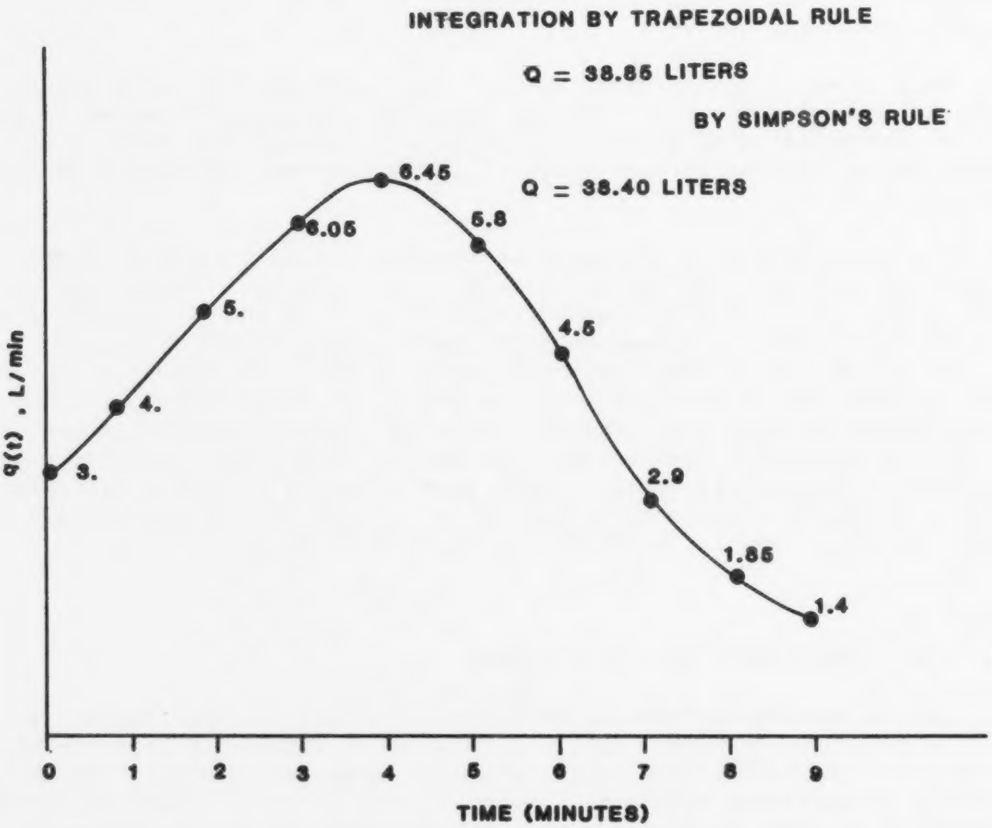


FIGURE 6.4. Example of numerical integration of a hydrograph using Trapezoidal and Simpson's Rule.

the total amount of material in the runoff water. An additional step is required, however. The concentration of the constituent in the water is first multiplied by the flow rate to give a mass flux (i.e., M/L x L/T = M/T). The mass flux curve is then integrated to obtain the total mass. This procedure is denoted by:

$$M = \int_0^t q(t)\, C_w(t)\, dt \tag{6.12}$$

Likewise, for a constituent adsorbed to sediment,

$$M = \int_0^t q(t)\, C_s(t)\, S(t)\, dt \tag{6.13}$$

where $S(t)$ = sediment concentration in the runoff water at time 't'

6.1.2.2 Frequency analysis

Many times it is useful to compare the frequency with which events of certain magnitudes occur in both the observed and simulated model outputs. This is accomplished by grouping the data to intervals and counting the number of occurrences in each interval in the observed and simulated data sets.

The construction of frequency histograms is a relatively straightforward procedure. Consider the flow data in Table 6.5. Twenty-one intervals of 25 ft^3/sec each were established (Table 6.6) and the number of flows in each of the intervals was counted. These counts appear in columns 3 and 4. The collective of these interval counts is called a frequency histogram. When the count in each interval is divided by the total number of occurrences in the histogram (columns 7 and 8) a relative frequency histogram results (i.e., the area under the histogram is unity). When these relative counts are summed over each interval, a cumulative relative frequency histogram results. This cumulative histogram can be used in statistical testing of model simulation results as discussed in the next section.

6.2 MODEL CALIBRATION AND VERIFICATION

The calibration process is performed to adjust model parameters so that simulated and observed system outputs agree within some measure of acceptance. Normally, this is accomplished in several stages. The logical order is to calibrate terrestrial hydrologic processes followed by stream hydraulics in order to properly simulate watershed hydrologic response. Simulated watershed outputs and changes in storage are compared whenever possible to observed values. Next, sediment washoff from the land surface followed by instream sediment process calibration is performed. Normally, after the system is calibrated, the simulation results are verified by

TABLE 6.5. INDEPENDENT OBSERVED AND SIMULATED FLOW TIME SERIES FOR THE ARROYO COLORADO AT WESLACO, TEXAS

S	O	S	O	S	O
124.95	126.	86.33	113.	151.45	304.
133.79	114.	82.96	149.	237.98	266.
192.50	113.	80.51	98.5	144.17	137.
130.98	102.	78.72	121.	134.161.	156.
140.75	92.5	107.33	111.	135.26	161.
114.95	95.7	81.31	114.	125.33	168.
119.38	141.	87.85	107.	119.13	139.
172.73	155.	267.97	121.	113.86	136.
162.89	106.	104.67	92.90	108.86	127.
117.13	108.	99.2	89.0	104.64	114.
138.81	140.	96.28	92.5	177.07	129.
138.17	111.	93.52	101.	112.92	111.
160.38	168.	136.07	94.3	107.71	135.
359.02	307.	223.16	188.	439.09	123.
104.71	119.	123.13	82.3	132.14	143.
88.97	149.	120.19	117.	123.83	168.
92.15	171.	119.05	105.	207.73	142.
116.61	174.	117.02	152.	132.62	129.
105.28	157.	171.82	138.	142.56	149.
91.82	139.	124.32	136.	128.76	106.
80.14	122.	126.95	150.	162.97	94.6
72.80	112.	138.16	148.	145.48	87.6
219.67	325.	146.92	144.	138.00	106.
78.48	132.	2465.2	1410.		
90.69	133.	222.22	131.		

simulating the outputs for a different period of time and comparing them to observed outputs.

Simulations rarely match observations exactly. There are several possibilities for explaining these discrepancies (Young and Alward, 1983):

- There may be errors in the mathematical description of the real-world process (i.e., the model algorithms)
- There may be errors in the observed measurements that have been made
- There may be errors in the input parameters or time series required to use the model

TABLE 6.6. FREQUENCY ANALYSIS OF FLOW DATA FROM THE ARROYO COLORADO

Interval (1)	Range (2)	# Occurrences (3)	(4)	Rel. Frequency (5)	(6)	Cum. Frequency (7)	(8)
		S	O	S	O	S	O
1	2 -25	0	0	0	0	0	0
2	25+-50	0	0	0	0	0	0
3	50+-75	1	0	0.0137	0	0.0137	0
4	75+-100	15	10	0.2055	0.1370	0.2192	.1370
5	100+-125	22	23	0.3014	0.3151	0.5206	0.4521
6	125+-150	18	24	0.2466	0.3288	0.7672	0.7809
7	150+-175	6	10	0.0822	0.1370	0.8494	0.9179
8	175+-200	2	1	0.0274	0.0137	0.8768	0.9316
9	200+-225	4	0	0.0548	0	0.9316	0.9316
10	225+-250	1	1	0.0137	0	0.9453	0.9316
11	250+-275	1	1	0.0137	0.0137	0.9590	09453
12	275+-300	0	0	0	0	0.9590	0.9453
13	300+-325	0	3	0	0.0411	0.9590	0.9864
14	325+-350	0	0	0	0	0.9590	0.9864
15	350+-375	1	0	0.0137	0	0.9727	0.9864
16	375+-400	0	0	0	0	0.9727	0.9864
17	400+-425	0	0	0	0	0.9727	0.9864
18	425+-450	1	0	0.0137	0	0.9864	0.9864
19	450+-475	0	0	0	0	0.9864	0.9864
20	475+-500	0	0	0	0	0.9864	0.9864
21	500+	1	1	0.0137	1.0137	1.0000	1.0000
TOTAL		73	73	1.0000	1.0000		

Figure 6.5 schematically shows where errors, or differences, can occur whenever model results are compared to field measurements from a natural system, such as a watershed. Similar to the categories listed above, Donigian (1982) has discussed the various types of errors that can occur in a model application, in terms of input errors, parameter errors, and output errors. Whenever a measurement or observation is made, a potential source of error is introduced. Although these errors may be difficult to detect, users of the data should be informed of the potential uncertainty involved and should consider these uncertainties during the model application.

In spite of these errors or differences, as discussed in Section 5 and noted above in the discussions that follow, the observed phenomena are assumed to be perfectly measured and the sources of error rest with the model and its various inputs. We will concern ourselves mainly with the analysis of simulated and observed time series to determine how well these two agree (i.e., goodness-of-fit) discounting any potential errors in the observed measurements. Goodness-of-fit can be used for two purposes: to ascertain when our calibration effort is good enough, and to ascertain if,

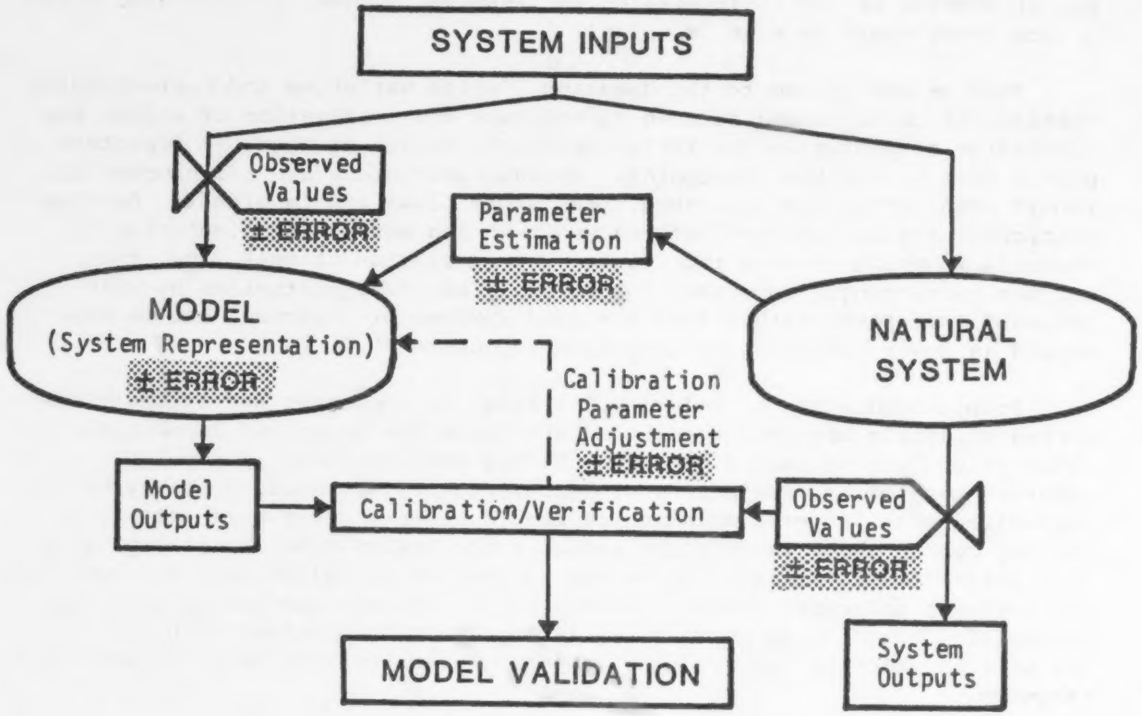

SYSTEM INPUTS
Observed Values
± ERROR
Parameter Estimation
± ERROR
MODEL (System Representation)
± ERROR
NATURAL SYSTEM
Calibration Parameter Adjustment
± ERROR
Model Outputs
Calibration/Verification
Observed Values
± ERROR
MODEL VALIDATION
System Outputs

FIGURE 6.5. Model vs. natural systems: inputs, outputs and errors (Donigian, 1982).

given a good calibration, we can expect the model to perfom well during another time period (verification).

Goodness-of-fit techniques can be applied to a number of statistics derived from the observed and simulated time series. Aitken (1973) demonstrated several techniques of model analysis including mean, standard deviation, coefficient of determination (r^2), coefficient of efficiency, serial correlation coefficients, sign tests, and residual mass curve coefficients. Young and Alward (1983) used the coefficient of variation and the Kolmogorov-Smirnov test in determining goodness-of-fit of ARM and NPS model calibrations. Chen et al. (1984) used student's t and F tests to test mean and variance, and the sign test, Kolmogorov-Smirnov (K-S test), Pearson product-moment correlation coefficient, and the McCuen-Snyder index (McCuen and Snyder, 1975) to indicate goodness-of-fit.

The fact is that there are a number of tests that can be used to test differences in various aspects of two time series. No single test will be best for all circumstances; multiple test statistics should be generated and analyzed. Goodness-of-fit tests should also be tailored to those aspects of the time series important to the problem at hand. For instance, if one is concerned with flooding, the tests should concentrate on peak flows; whereas if one is interested in dissolved oxygen, correct simulation of low flows would be most important.

Thus we are guided to the question, "Which variables and corresponding statistical tests should be used to evaluate the calibration of models for simulation of pesticide runoff?". Obviously volume of water is important purely from a dilution standpoint. Because pesticides are transported in runoff events from the watershed, peak storm flows are important. Because pesticides are partitioned between sediment and water, the simulation of sediment movement also is important. The simulation of peak flow, then, becomes increasingly important for strongly adsorbed pesticides because sediment transport, either from the land surface or instream, can be described as power functions of flow with exponents >1.0.

Proper simulation of velocity (or flow) is important for strongly adsorbed chemicals when the velocities are above the scour and deposition shear velocities of particles to which they are attached. For weakly adsorbed pesticides, sediment and, hence, peak flows should probably be deemphasized with proper simulation of runoff volumes given more attention. The key concept here is that the emphasis for analysis may shift depending upon pesticide properties. If we are interested in calibrating the hydrology and sediment transport model to enable us to simulate pesticides with wide ranges of adsorption properties, it is important to simulate both flow rate (as well as velocity) and volumes properly, over the full range of watershed response.

In addition, models can be calibrated in the frequency or real time domains. That is, we can use tests to tell us whether the frequency responses of the simulated and observed data are not different or if the point-to-point (real time) simulated and observed results are not statistically different.

The K-S test is sensitive to a wide range of alternatives, such as differences in central tendency as well as differences in dispersion. It keys on the maximum difference between the cumulative frequency distributions of two data sets. Thus it considers mass of the distributions (i.e., volume) as well as the closeness of frequency response of the two distributions.

If point-to-point simulation of observed values is important (e.g., timing of peaks and valleys) then a "real-time" approach, rather that one based purely on frequencies, must be taken. Regression analysis is a suitable tool for this for two reasons:

- it measures the point-to-point correlation between observed and simulated data
- tests are available for inference concerning the slope and intercept of the regression line

It can also be used to provide information about the relative masses of the two samples because the means of both enter into the calculations of the least squares method.

These two methods have been chosen for discussion as ways to test observed and simulated flow and sediment concentrations for model calibration purposes. There are some pitfalls, however, in using these methods on time series data that should be avoided. These caveats are discussed in the following sections, in which is discussed the analysis of data and application of the tests.

While the value of statistics in calibration and verification is enormous, rigorous comparisons of time series data for these purposes have been largely neglected. Typically, the judgment of the modeler has been the key criteria in judging goodness-of-fit. What is advocated here is intelligent use of the tools available to us for making the judgement of "how-good-is-good." Certainly, the simulated and observed data should in every case be plotted and inspected visually. We can usually tell an "excellent" fit from an "atrocious" one. In the "atrocious" case, statistical measures may be of little value. When observed and simulated values are closer, however, statistical measures can be valuable in determining whether changes in model parameters are actually "improving" the fit. Valuable time and effort can be wasted by trying to "perfect" the calibration.

6.2.1 The Kolmogorov-Smirnov Two-Sample Test

The Kolmogorov-Smirnov two-sample test (K-S test) requires that cumulative frequency distributions be developed from the data. In our applications these data are almost always a time series and are nearly always serially correlated to some extent. This fact requires some special preprocessing of the data before the K-S test can be applied. This will be discussed later.

First, let us show how the K-S two-sample test is used. The following discussion is taken from Siegel (1954).

> "The Kolmogorov-Smirnov two sample test is a test of whether two independent samples have been drawn from the same population (or from populations with the same distribution). The two-tailed test is sensitive to any kind of difference in the distributions from which the two samples were drawn - differences in location (central tendency), in dispersion, in skewness, etc. The one-tailed test is used to decide whether or not the values of the population from which one of the samples was drawn are stochastically larger than the values of the population from which the other sample was drawn. This two-sample test is concerned with the agreement between two cumulative distributions.
>
> If the two samples have in fact been drawn from the same population distribution, then the cumulative distributions of both samples may be expected to be fairly close to each other, inasmuch as they both should show only random deviations from the population distribution. If the

two-sample cumulative distributions are "too far apart" at any point, this suggests that the samples come from different populations. Thus a large enough deviation between the two sample cumulative distributions is evidence for rejecting H_o (i.e., the hypothesis of same distributions). Applying the Kolmogorov-Smirnov two-sample test, we make a cumulative frequency distribution for each sample of observations, using the same intervals for both distributions. For each interval, then, we subtract one step function from the other. The test focuses on the largest of these observed deviations.

Let $^{S}n_1$ (X) = the observed cumulative step function of one of the samples, that is, $^{S}n_2$ (X) = K/n_1, where K = the number of scores equal to or less than X. And let $^{S}n_1$ (X) = K/n_2. Now the Kolmogorov-Smirnov two-sample test focuses on:

$$D = \text{maximum } [{}^{S}n_1 (X) - {}^{S}n_2 (X)] \qquad (6.14)$$

for a one-tailed test, and on:

$$D = \text{maximum } |{}^{S}n_1 (X) - {}^{S}n_2 (X)| \qquad (6.15)$$

for a two-tailed test. The sampling distribution of D is known and the probabilities associated with the occurrence of values as large as an observed D under the null hypothesis (that the two samples have come from the same distribution) have been tabled.

Notice that, for a one-tailed test, we find the maximum value of D in the predicted direction [by equation 6.14] and that, for a two-tailed test, we find the maximum absolute value of D [by equation 6.15], i.e., we find the maximum deviation irrespective of direction. This is because in the one-tailed test, H_1 (the alternative hypothesis) is that the population values from which one of the samples was drawn are stochastically larger than the population values from which the other sample was drawn; whereas in the two-tailed test, H_1 is simply that the two samples are from different populations."

The analysis of data to produce a cumulative frequency distribution was discussed earlier. When using the K-S test, it is desirable to use as many grouping intervals as are feasible. If individual values are available, it is recommended that they be used in forming the empirical cumulative distribution functions for subsequent comparison by the K-S technique.

One of the assumptions of the K-S test is that observations within a sample are independent. The problem with applying the K-S test to time series data is that, more often than not, this assumption is not met. This is due to the fact that most natural time series (e.g., flow, sediment concentrations, etc.) are serially correlated. This is especially true for larger watersheds where streamflow, sediment transport, etc. are continuous. Less serial correlation will be evident in data from smaller areas. In order to use a K-S test, any serial correlation in the data must be removed from the sample.

6.2.1.1 Tests for serial correlation--

The way to detect serial correlation in a data set is to compute the Pearson product-moment correlation coefficient of each data point with its preceding value, which is called the lag 1 serial-(or auto-) correlation coefficent and is denoted r(1). If the data sets are lagged again so that each data point is correlated with the second preceding point then the lag 2 coefficient, r(2), results. This process can be continued and serial correlation coefficients r(k) can be computed (see Yevjevich, 1972 for a complete discussion). A plot of r(k) versus k is called a serial correlogram. An example is shown in Figure 6.6.

Notice that generally the r(k) decreases as k increases until they hover close to or cycle around zero. Confidence limits (dashed lines) can be computed around zero. Once the correlation coefficients consistently fall inside these bands, we can say that they are statistically not different from zero for this sample size and confidence level (for computation limits see Anderson, 1942 or Jenkins and Watts, 1969). In the example correlogram of Figure 6.7, then, we can say that approximately every 10th point (streamflow value for every 10th day, in this case), is uncorrelated (i.e., independent). To apply the K-S test, then, these two time series could be sampled by taking every 10th point and using this new series to form the cumulative distribution histograms.

While this method will virtually guarantee independence, others might also be tried. Another method would be to aggregate data and perform the test on monthly as opposed to daily data, for instance. While more aggregated series generally have less serial correlation, this method does not guarantee independence.

6.2.1.2 Example application

Data from the HSPF calibration of the Arroyo Colorado watershed in Texas (Dean et al., 1984) were used to construct the following example of the application of the K-S test to serially correlated daily streamflow data.

From the serial correlogram in Figure 6.7, it was noted that every 10th point (or day) in both the simulated and observed time series is independent. Therefore the original two time series of 730 values were sampled by selecting every 10th value in each. The resulting independent subsets were shown in Table 6.5.

Table 6.6 shows the frequency and cumulative frequency distributions of the observed and simulated independent series. The final column, |D| is the absolute difference between the observed and simulated cumulative frequency distributions. The maximum of these occurred in interval 4, therefore $D_{max} = 0.0822$. The value of D at a 0.05 (5%) probability level is calculated from:

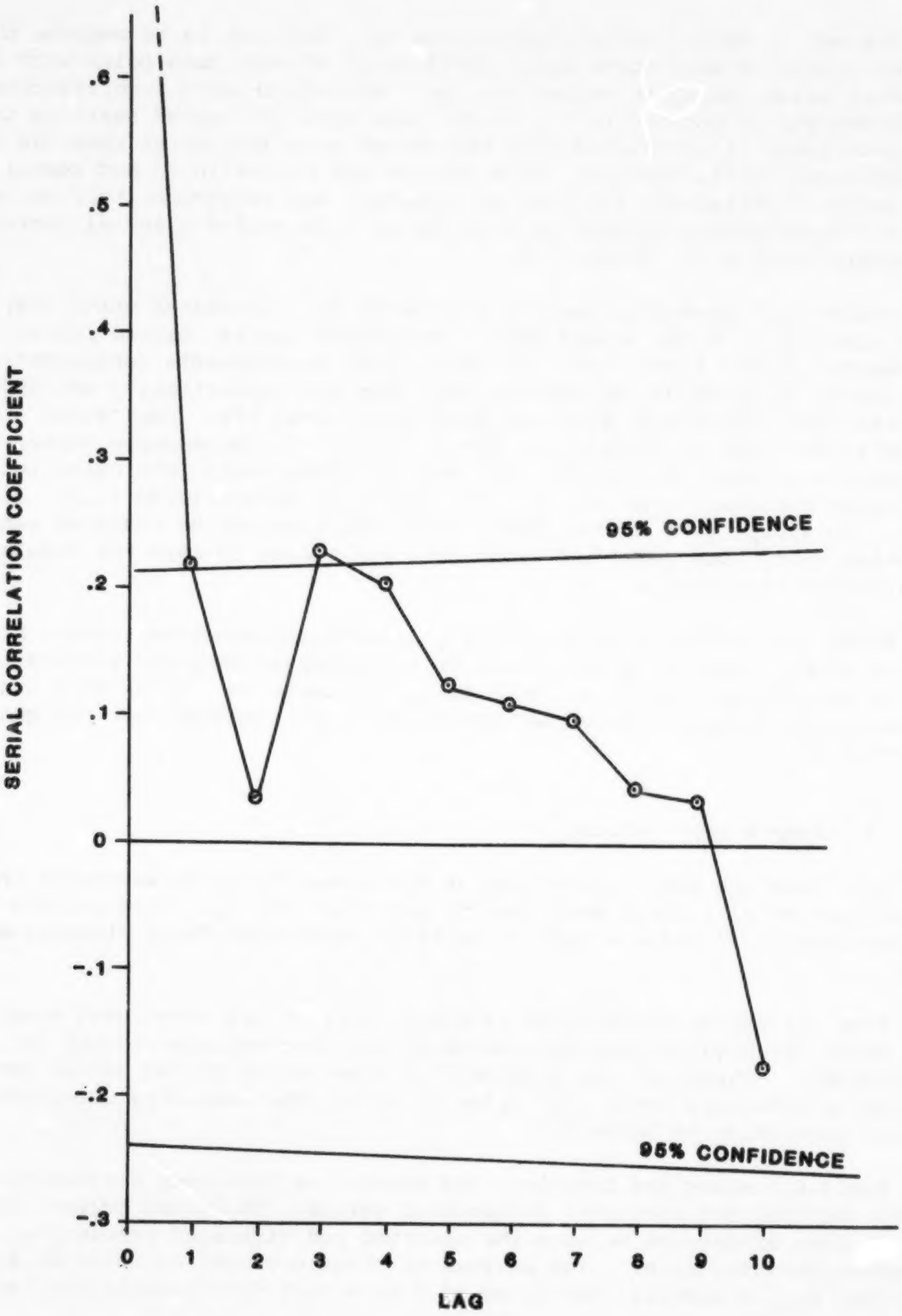


FIGURE 6.6. Serial correlogram of residuals.

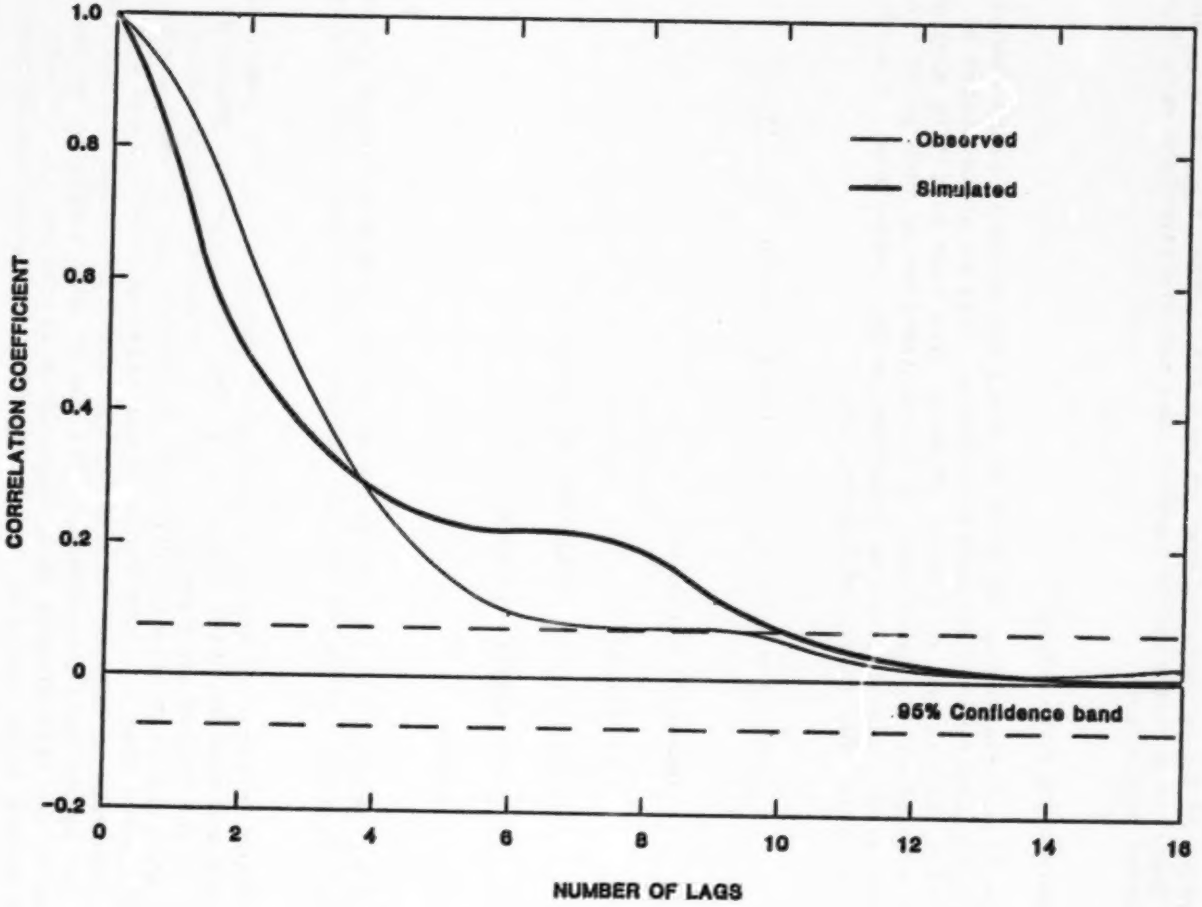


FIGURE 6.7. Serial correlogram of observed and simulated mean daily flow for the Main Floodway at Weslaco.

$$D_{0.05} = 1.36 \sqrt{(n_1+n_2)/(n_1\ n_2)} \qquad (6.16)$$

Table 6.7 shows how D is calculated for different significance levels, where n_1 and n_2 are the respective sample sizes (in this case $n_1 = n_2 = 73$). Thus the value of $D_{0.05}$ is calculated to be 0.225. Thus, $D_{max} < D_{0.05}$ and therefore there is no evidence to suggest that the distributions were drawn from different populations.

6.2.2 Linear Regression Analysis

Simple linear regression analysis involves the point-to-point comparison of an independent and a dependent variable. This is accomplished by fitting a line through the x, y pairs of data. The line is fit by minimizing the sum of squares of the deviations in the y-direction of each point from the best-fit line. The line can be described by two parameters: a slope and a y-intercept. The model, of course, is:

$$y_i = \alpha + \beta\, x_i + \varepsilon_i \quad , \quad i = 1, \ldots, n \qquad (6.17)$$

where y_i = dependent variable

α = y-intercept

β = slope of the linear relationship

x_i = independent variable

ε_i = error

The method for determining the coefficients in Equation 6.17 can be found in a number of texts (Bhattacharyya and Johnson, 1977; Haan, 1977; Fisher, 1981).

The major interest in applying regression analysis for the comparison of simulated and observed time series is to test the slope and intercept (α and β) of the regression equation. The aim in model development is to obtain an α not statistically different from zero, and a β not statistically different from 1. Confidence in our inference about α and β is enhanced, however, by knowing that the linear model is a good one and that the good fit is not just fortuitous. This can be done simply by visual inspection of the line plotted on a scattergram of the points. A more objective method is by computing the coefficient of determination from the data. This coefficient is computed by:

$$r^2 = 1 - \frac{SSE}{SST} \qquad (6.18)$$

TABLE 6.7. CRITICAL VALUES IN THE KOLMOGOROV-SMIRNOV TESTS (Chemical Rubber Co., 1974)

CRITICAL VALUES OF *D* IN THE KOLMOGOROV-SMIRNOV TWO-SAMPLE TEST

(Large samples: two-tailed test)

Level of significance	Value of *D* so large as to call for rejection of H_0 at the indicated level of significance, where $D = \text{maximum } \lvert F_{n_1}(X) - F_{n_2}(X) \rvert$
.10	$1.22\sqrt{\frac{n_1+n_2}{n_1n_2}}$
.05	$1.36\sqrt{\frac{n_1+n_2}{n_1n_2}}$
.025	$1.48\sqrt{\frac{n_1+n_2}{n_1n_2}}$
.01	$1.63\sqrt{\frac{n_1+n_2}{n_1n_2}}$
.005	$1.73\sqrt{\frac{n_1+n_2}{n_1n_2}}$
.001	$1.95\sqrt{\frac{n_1+n_2}{n_1n_2}}$

CRITICAL VALUES FOR THE KOLMOGOROV-SMIRNOV TEST OF H_0: $F_1(x) = F_2(x)$

		Sample size n_1											
		1	2	3	4	5	6	7	8	9	10	12	15
Sample size n_2	1	* *	* *	* *	* *	* *	* *	* *	* *	* *	* *		
	2		* *	* *	* *	* *	* *	* *	7/8 *	16/18 *	9/10 *		
	3			* *	* *	12/15 *	5/6 *	18/21 *	18/24 *	7/9 8/9		9/12 11/12	
	4				3/4 *	16/20 *	9/12 10/12	21/28 24/28	6/8 7/8	27/36 32/36	14/20 16/20	8/12 10/12	
	5					4/5 4/5	20/30 25/30	25/35 30/35	27/40 32/40	31/45 36/45	7/10 8/10		10/15 11/15
	6						4/6 5/6	29/42 35/42	16/24 18/24	12/18 14/18	19/30 22/30	7/12 9/12	
	7							5/7 5/7	35/56 42/56	40/63 47/63	43/70 53/70		
	8								5/8 6/8	45/72 54/72	23/40 28/40	14/24 16/24	
	9									5/9 6/9	52/90 62/90	20/36 24/36	
	10										6/10 7/10		15/30 19/30
	12											6/12 7/12	30/60 35/60
	15												7/15 8/15

Reject H_0 if

$D = \max \lvert F_{n_1}(x) - F_{n_2}(x) \rvert$

exceeds the tabulated value. The upper value gives a level at most .05 and the lower value gives a level at most .01.

Note 1: Where * appears, do not reject H_0 at the given level.
Note 2: For large values of n_1 and n_2, the following approximate formulas may be used:

$$\alpha = .05: \quad 1.36\sqrt{\frac{n_1+n_2}{n_1n_2}}$$

$$\alpha = .01: \quad 1.63\sqrt{\frac{n_1+n_2}{n_1n_2}}$$

where

r^2 = coefficient of determination

SSE = sums of squares of the residuals (deviations in the y-direction from the best fit line)

SST = (n-1) times the sample variance of the dependent y observations

n = total number of x, y points

The coefficient of determination, r^2, can take on values between 0 and 1. Values closer to 1 indicate that the points are closer to the best fit line. In fact the value of r^2 may be thought of as the fraction of the total variability in y that is explained by the linear relationship. It should be noted that, for simple bivariate (x,y) regression, r^2 is identically the square of the Pearson product-moment correlation coefficient. For multiple regression (more than one independent variable), however, this is not the case (Fisher, 1981).

There are some special considerations for applying regression techniques to the problem of comparing two time-series. Yevjevich (1972b) states that the method of least squares only gives reliable estimates of α and β if two conditions are met. First, the residuals must be independent and, second, the variance of the residuals must not be a function of the independent variable x.

The first assumption is equivalent to saying that no time dependent or serial correlation exists among the residuals. This can easily be checked by the method of constructing a serial correlogram using the residuals.

The second assumption is referred to as homoscedasticity. If the scatter of the x, y points around the regression line tends to increase as the values of x increase, then the assumption is violated. The easiest way of dealing with this problem is to transform the data so that the variance is approximately equal along the regression line. The regression analysis is then performed on the transformed data.

No further assumptions are required for assuming that the estimates of α and β are unbiased. For the purposes of making inferences about the regression coefficients, however, the distribution of the residuals around the regression line should be normal. Bhattacharyya and Johnson (1977) state that a moderate deviation from normality does not impair inference especially when the data set is large.

Given that these conditions are met, we can test α and β to see whether they meet the requirements for a good fit of the simulated to observed data.

6.2.2.1 Significance tests for α and β

To test the hypothesis that β equals unity, the t statistic is computed:

$$t = \frac{b-1}{S_b} \qquad (6.19)$$

where $b = S_{xy}/S_{xx}$ (the estimate of β) (6.20)

$$S_b = \sqrt{MSE/S_{xx}}$$

$$S_{xx} = \sum (X_i-\bar{X})^2$$

$$S_{xy} = \sum (X_i-\bar{X})Y_i$$

$$S_{yy} = \sum (y_i-\bar{y})^2$$

$$MSE = (S_{yy} - S^2_{xy}/S_{xx})/(n-2)$$

The value of t can be compared to values of critical t at some probability level with n-2 degrees of freedom.

The parameter $\alpha = 0$ can be tested by:

$$t = \frac{a}{S_a} \qquad (6.22)$$

where $a = \bar{y} - b\,\bar{x}$

$$S_a = \sqrt{MSE} \cdot \sqrt{\frac{1}{n} + \frac{\bar{x}^2}{S_{xx}}}$$

with n-2 degrees of freedom.

6.2.2.2 Example regression analysis

An example of the above procedures is provided below using the data from the Arroyo Colorado (Table 5.5). The plotted data are shown in Figure 6.8. The grouping of most of the data at the 90-160 ft^3/sec level with only a few points at higher flows, however, may lead to some problems that will be discussed later. Notice that there is one point (x=1410, y=2465.2) that does not appear on the graph. From the least squares we derive the parameter estimates:

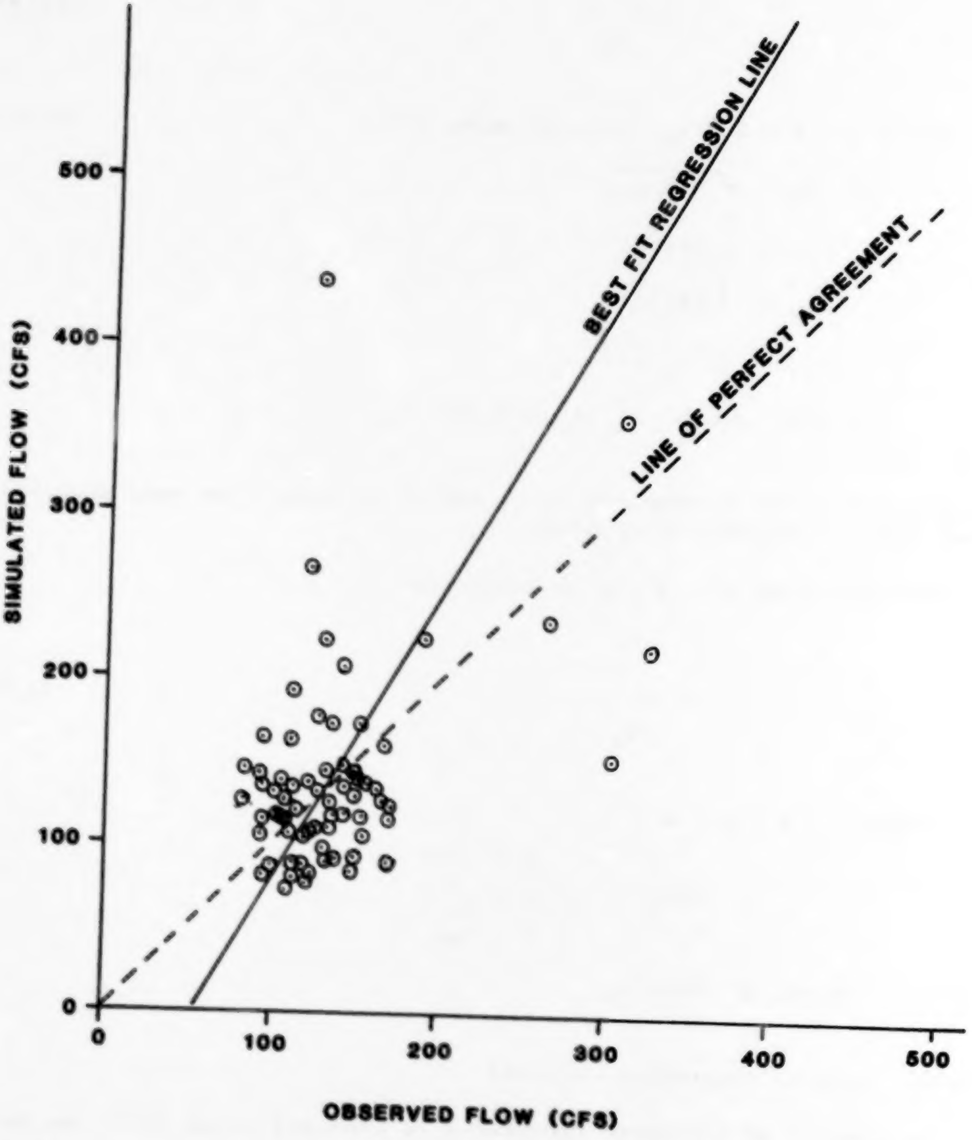


FIGURE 6.8. Regression analysis of observed and simulated flows for the Arroyo Colorado.

$$a = 94.06$$

$$b = 1.71$$

The r^2 value is 0.92. It should be pointed out here that spurious (inflated estimates of correlation as evidenced by high values of 'r') correlation can arise out of the type of situation represented in Figure 6.8 where most of the data are clustered except for a few outlying points. In fact, the reason that the slope is so large is due to the influence of the (x,y) pair (1410, 2465). If this point were eliminated, the r^2 value would drop drastically but the slope may or may not be closer to unity. Haan (1977) provides a more in-depth discussion of spurious correlation.

Once the least squares line is defined it can be plotted on the scattergram and visually compared to the line of perfect agreement. These are also plotted in Figure 6.8.

The residuals are tabulated in Table 6.8. An autocorrelogram of the residuals was shown in Figure 6.6. The correlogram indicates that although one or two of the coefficients lie outside the 95% confidence band, on the whole the correlogram is well contained indicating an independent series.

A test for normality of the residuals is done as follows. Compute the frequency histogram of the residuals as shown in Table 6.9. Then compute the mean and variance of the residuals and compute the standard normal deviate value of the upper end of the frequency class. The standard normal deviate is computed by:

$$Z = \frac{e_y - \overline{e}_y}{s_e} \tag{6.23}$$

where e_y = value of the upper limit of a frequency class

$\overline{e}_y$ = mean of the residuals

s_e = standard deviation of the residuals

In this case $s_e = 79.296$. Once the standard normal deviates (SND) are found, the cumulative area under the normal curve lying to the left of the SND can be found in Table 6.10. Subtracting the cumulative probabilities, one can find the individual cell probabilities (column 4). Multiplication by the number of observations (73) gives the expected cell frequency.

The test for goodness-of-fit is Pearson's χ^2. By using the formula below, the χ^2 statistic can be found:

TABLE 6.8. RESIDUAL OF REGRESSION OF ARROYO COLORADO SIMULATED AND OBSERVED STREAMFLOW $(S-(\alpha + \beta O)$

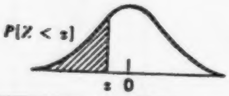
Data Point #	Residual	Data Point #	Residual	Data Point #	Residual
1	3.26	26	-13.10	51	-275.02
2	32.65	27	-78.11	52	-123.43
3	93.07	28	5.09	53	3.65
4	50.39	29	-34.41	54	-38.30
5	76.42	30	11.33	55	-46.36
6	45.14	31	-19.83	56	-68.27
7	-27.99	32	-1.30	57	-24.82
8	1.39	33	154.84	58	-24.45
9	75.45	34	39.66	59	-14.54
10	26.26	35	40.87	60	3.50
11	-6.85	36	31.95	61	50.24
12	42.17	37	14.64	62	16.92
13	-33.22	38	68.66	63	-29.39
14	-72.59	39	-4.69	64	322.54
15	-4.99	40	76.27	65	-18.66
16	-72.10	41	13.91	66	-69.77
17	-106.59	42	33.32	67	58.65
18	-87.27	43	-49.19	68	5.80
19	-69.49	44	29.58	69	-18.51
20	-52.13	45	-14.49	70	41.32
21	-34.70	46	-35.83	71	45.05
22	-24.92	48	-21.20	72	89.54
23	-242.76	48	-5.59	73	50.56
24	-33.48	49	144.95		
25	-42.98	50	91.97		

TABLE 6.9. COMPUTATION OF THE χ^2 STATISTIC FOR THE TEST OF NORMALITY OF RESIDUALS

Cell No.	Range	Observed Frequency	Standard Normal Deviate	Cumulative Normal Prob.	Cell Probability	Expected Frequency	$\frac{(O-E)^2}{E}$
1	$-\infty$ to -100.	4	-1.261	.1038	0.1038	7.577	1.689
2	-100 to -75.	2	-.9458	.1736	0.0698	5.095	1.883
3	-75 to -50.	6	-.6305	.2643	0.0907	6.621	0.058
4	-50 to -25.	11	-.3154	.3783	0.1140	8.322	0.861
5	-25 to 0	15	0	.5	0.1217	8.88	4.497
6	0 to 25	10	.3154	.6217	0.1217	8.88	0.138
7	25 to 50	10	.6305	.7357	0.1140	8.322	0.336
8	50 to 75	5	.9458	.8264	0.0907	6.621	0.394
9	75 to 100	7	1.261	.8962	0.0698	5.095	0.715
10	100	3		1.000	0.1038	7.577	2.744

$$\Sigma \frac{(O-E)^2}{E} = 13.312$$

TABLE 6.10. STANDARD NORMAL PROBABILITIES



z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
−3.5	.0002	.0002	.0002	.0002	.0002	.0002	.0002	.0002	.0002	.0002
−3.4	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0003	.0002
−3.3	.0005	.0005	.0005	.0004	.0004	.0004	.0004	.0004	.0004	.0003
−3.2	.0007	.0007	.0006	.0006	.0006	.0006	.0006	.0005	.0005	.0005
−3.1	.0010	.0009	.0009	.0009	.0008	.0008	.0008	.0008	.0007	.0007
−3.0	.0013	.0013	.0013	.0012	.0012	.0011	.0011	.0011	.0010	.0010
−2.9	.0019	.0018	.0018	.0017	.0016	.0016	.0015	.0015	.0014	.0014
−2.8	.0026	.0025	.0024	.0023	.0023	.0022	.0021	.0021	.0020	.0019
−2.7	.0035	.0034	.0033	.0032	.0031	.0030	.0029	.0028	.0027	.0026
−2.6	.0047	.0045	.0044	.0043	.0041	.0040	.0039	.0038	.0037	.0036
−2.5	.0062	.0060	.0059	.0057	.0055	.0054	.0052	.0051	.0049	.0048
−2.4	.0082	.0080	.0078	.0075	.0073	.0071	.0069	.0068	.0066	.0064
−2.3	.0107	.0104	.0102	.0099	.0096	.0094	.0091	.0089	.0087	.0084
−2.2	.0139	.0136	.0132	.0129	.0125	.0122	.0119	.0116	.0113	.0110
−2.1	.0179	.0174	.0170	.0166	.0162	.0158	.0154	.0150	.0146	.0143
−2.0	.0228	.0222	.0217	.0212	.0207	.0202	.0197	.0192	.0188	.0183
−1.9	.0287	.0281	.0274	.0268	.0262	.0256	.0250	.0244	.0239	.0233
−1.8	.0359	.0351	.0344	.0336	.0329	.0322	.0314	.0307	.0301	.0294
−1.7	.0446	.0436	.0427	.0418	.0409	.0401	.0392	.0384	.0375	.0367
−1.6	.0548	.0537	.0526	.0516	.0505	.0495	.0485	.0475	.0465	.0455
−1.5	.0668	.0655	.0643	.0630	.0618	.0606	.0594	.0582	.0571	.0559
−1.4	.0808	.0793	.0778	.0764	.0749	.0735	.0721	.0708	.0694	.0681
−1.3	.0968	.0951	.0934	.0918	.0901	.0885	.0869	.0853	.0838	.0823
−1.2	.1151	.1131	.1112	.1093	.1075	.1056	.1038	.1020	.1003	.0985
−1.1	.1357	.1335	.1314	.1292	.1271	.1251	.1230	.1210	.1190	.1170
−1.0	.1587	.1562	.1539	.1515	.1492	.1469	.1446	.1423	.1401	.1379
−.9	.1841	.1814	.1788	.1762	.1736	.1711	.1685	.1660	.1635	.1611
−.8	.2119	.2090	.2061	.2033	.2005	.1977	.1949	.1922	.1894	.1867
−.7	.2420	.2389	.2358	.2327	.2297	.2266	.2236	.2206	.2177	.2148
−.6	.2743	.2709	.2676	.2643	.2611	.2578	.2546	.2514	.2483	.2451
−.5	.3085	.3050	.3015	.2981	.2946	.2912	.2877	.2843	.2810	.2776
−.4	.3446	.3409	.3372	.3336	.3300	.3264	.3228	.3192	.3156	.3121
−.3	.3821	.3783	.3745	.3707	.3669	.3632	.3594	.3557	.3520	.3483
−.2	.4207	.4168	.4129	.4090	.4052	.4013	.3974	.3936	.3897	.3859
−.1	.4602	.4562	.4522	.4483	.4443	.4404	.4364	.4325	.4286	.4247
−.0	.5000	.4960	.4920	.4880	.4840	.4801	.4761	.4721	.4681	.4641

TABLE 6.10 (Cont'd). STANDARD NORMAL PROBABILITIES

z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
.0	.5000	.5040	.5080	.5120	.5160	.5199	.5239	.5279	.5319	.5359
.1	.5398	.5438	.5478	.5517	.5557	.5596	.5636	.5675	.5714	.5753
.2	.5793	.5832	.5871	.5910	.5948	.5987	.6026	.6064	.6103	.6141
.3	.6179	.6217	.6255	.6293	.6331	.6368	.6406	.6443	.6480	.6517
.4	.6554	.6591	.6628	.6664	.6700	.6736	.6772	.6808	.6844	.6879
.5	.6915	.6950	.6985	.7019	.7054	.7088	.7123	.7157	.7190	.7224
.6	.7257	.7291	.7324	.7357	.7389	.7422	.7454	.7486	.7517	.7549
.7	.7580	.7611	.7642	.7673	.7703	.7734	.7764	.7794	.7823	.7852
.8	.7881	.7910	.7939	.7967	.7995	.8023	.8051	.8078	.8106	.8133
.9	.8159	.8186	.8212	.8238	.8264	.8289	.8315	.8340	.8365	.8389
1.0	.8413	.8438	.8461	.8485	.8508	.8531	.8554	.8577	.8599	.8621
1.1	.8643	.8665	.8686	.8708	.8729	.8749	.8770	.8790	.8810	.8830
1.2	.8849	.8869	.8888	.8907	.8925	.8944	.8962	.8980	.8997	.9015
1.3	.9032	.9049	.9066	.9082	.9099	.9115	.9131	.9147	.9162	.9177
1.4	.9192	.9207	.9222	.9236	.9251	.9265	.9279	.9292	.9306	.9319
1.5	.9332	.9345	.9357	.9370	.9382	.9394	.9406	.9418	.9429	.9441
1.6	.9452	.9463	.9474	.9484	.9495	.9505	.9515	.9525	.9535	.9545
1.7	.9554	.9564	.9573	.9582	.9591	.9599	.9608	.9616	.9625	.9633
1.8	.9641	.9649	.9656	.9664	.9671	.9678	.9686	.9693	.9699	.9706
1.9	.9713	.9719	.9726	.9732	.9738	.9744	.9750	.9756	.9761	.9767
2.0	.9772	.9778	.9783	.9788	.9793	.9798	.9803	.9808	.9812	.9817
2.1	.9821	.9826	.9830	.9834	.9838	.9842	.9846	.9850	.9854	.9857
2.2	.9861	.9864	.9868	.9871	.9875	.9878	.9881	.9884	.9887	.9890
2.3	.9893	.9896	.9898	.9901	.9904	.9906	.9909	.9911	.9913	.9916
2.4	.9918	.9920	.9922	.9925	.9927	.9929	.9931	.9932	.9934	.9936
2.5	.9938	.9940	.9941	.9943	.9945	.9946	.9948	.9949	.9951	.9952
2.6	.9953	.9955	.9956	.9957	.9959	.9960	.9961	.9962	.9963	.9964
2.7	.9965	.9966	.9967	.9968	.9969	.9970	.9971	.9972	.9973	.9974
2.8	.9974	.9975	.9976	.9977	.9977	.9978	.9979	.9979	.9980	.9981
2.9	.9981	.9982	.9982	.9983	.9984	.9984	.9985	.9985	.9986	.9986
3.0	.9987	.9987	.9987	.9988	.9988	.9989	.9989	.9989	.9990	.9990
3.1	.9990	.9991	.9991	.9991	.9992	.9992	.9992	.9992	.9993	.9993
3.2	.9993	.9993	.9994	.9994	.9994	.9994	.9994	.9995	.9995	.9995
3.3	.9995	.9995	.9995	.9996	.9996	.9996	.9996	.9996	.9996	.9997
3.4	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9998
3.5	.9998	.9998	.9998	.9998	.9998	.9998	.9998	.9998	.9998	.9998

$$\chi^2 = \sum_{i}^{k} \frac{(O_i - E_i)^2}{E_i} \tag{6.24}$$

where O_i = observed cell frequency

E_i = expected cell frequency

k = number of cells

The χ^2 statistic is shown in the table also. From Table 6.11, which shows the percentage points of the χ^2 distribution, for k-1 degrees of freedom and 0.05 probability, the χ^2 value is 16.919. Therefore we cannot reject the hypothesis that the distribution of residuals is non-normal because since our χ^2 of 13.3 does not exceed the $\chi^2_{9,0.05}$ value of 16.9.

Since we have established that the residuals are independent and normally distributed, we can perform the t-test to infer whether β differs from unity and α differs from zero. From the computations, we find that the t for β is 11.14 and the t for α is -6.75. From the t tables (Table 6.12), we can find critical values of t at the 0.05 probability level with n-2 (73) degrees of freedom. Since this value should be <1.6, we can conclude that the β is different from unity and the α is different from zero. Thus the point-to-point correlation between our model and the observed data is imperfect.

6.3 MODEL APPLICATION AND SENSITIVITY TESTING

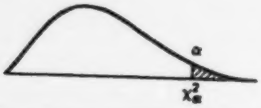
The successful integration of site-specific information and model calibration is the first step in performing exposure assessments of pesticide runoff under different hydrologic responses.

The concept of risk reflects the probability of causing an effect and implies that an organism must first have been exposed to the pesticide for sufficient time and at a high enough concentration to inflict damage. The use of continuous simulation models to generate data to derive probability statements about hydrological events is an accepted technique. Simulation models have been used to estimate probabilities of environmental exposure expressed as cumulative frequency distributions.

Frequency distributions of the mass of pesticide lost from runoff or expressed as concentrations in stream channels appear to be valuable tools to assist in assigning risk to pesticide use.

The many climatologic, hydrologic, agronomic, and pesticide characteristics create numerous and diverse scenarios that may have to be investigated when simulating pesticide runoff. The use of sensitivity analysis can,

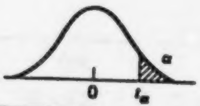
TABLE 6.11. PERCENTAGE POINTS OF X^2 DISTRIBUTIONS



d.f. \ α	.995	.990	.975	.950	.050	.025	.010	.005
1	392704×10^{-10}	157088×10^{-9}	982069×10^{-9}	393214×10^{-8}	3.84146	5.02389	6.63490	7.87944
2	.0100251	.0201007	.0506356	.102587	5.99147	7.37776	9.21034	10.5966
3	.0717212	.114832	.215795	.351846	7.81473	9.34840	11.3449	12.8381
4	.206990	.297110	.484419	.710721	9.48773	11.1433	13.2767	14.8602
5	.411740	.554300	.831211	1.145476	11.0705	12.8325	15.0863	16.7496
6	.675727	.872085	1.237347	1.63539	12.5916	14.4494	16.8119	18.5476
7	.989265	1.239043	1.68987	2.16735	14.0671	16.0128	18.4753	20.2777
8	1.344419	1.646482	2.17973	2.73264	15.5073	17.5346	20.0902	21.9550
9	1.734926	2.087912	2.70039	3.32511	16.9190	19.0228	21.6660	23.5893
10	2.15585	2.55821	3.24697	3.94030	18.3070	20.4831	23.2093	25.1882
11	2.60321	3.05347	3.81575	4.57481	19.6751	21.9200	24.7250	26.7569
12	3.07382	3.57056	4.40379	5.22603	21.0261	23.3367	26.2170	28.2995
13	3.56503	4.10691	5.00874	5.89186	22.3621	24.7356	27.6883	29.8194
14	4.07468	4.66043	5.62872	6.57063	23.6848	26.1190	29.1413	31.3193
15	4.60094	5.22935	6.26214	7.26094	24.9958	27.4884	30.5779	32.8013
16	5.14224	5.81221	6.90766	7.96164	26.2962	28.8454	31.9999	34.2672
17	5.69724	6.40776	7.56418	8.67176	27.5871	30.1910	33.4087	35.7185
18	6.26481	7.01491	8.23075	9.39046	28.8693	31.5264	34.8053	37.1564
19	6.84398	7.63273	8.90655	10.1170	30.1435	32.8523	36.1908	38.5822
20	7.43386	8.26040	9.59083	10.8508	31.4104	34.1696	37.5662	39.9968
21	8.03366	8.89720	10.28293	11.5913	32.6705	35.4789	38.9321	41.4010
22	8.64272	9.54249	10.9823	12.3380	33.9244	36.7807	40.2894	42.7956
23	9.26042	10.19567	11.6885	13.0905	35.1725	38.0757	41.6384	44.1813
24	9.88623	10.8564	12.4011	13.8484	36.4151	39.3641	42.9798	45.5585
25	10.5197	11.5240	13.1197	14.6114	37.6525	40.6465	44.3141	46.9278
26	11.1603	12.1981	13.8439	15.3791	38.8852	41.9232	45.6417	48.2899
27	11.8076	12.8786	14.5733	16.1513	40.1133	43.1944	46.9630	49.6449
28	12.4613	13.5648	15.3079	16.9279	41.3372	44.4607	48.2782	50.9933
29	13.1211	14.2565	16.0471	17.7083	42.5569	45.7222	49.5879	52.3356
30	13.7867	14.9535	16.7908	18.4926	43.7729	46.9792	50.8922	53.6720
40	20.7065	22.1643	24.4331	26.5093	55.7585	59.3417	63.6907	66.7659
50	27.9907	29.7067	32.3574	34.7642	67.5048	71.4202	76.1539	79.4900
60	35.5346	37.4848	40.4817	43.1879	79.0819	83.2976	88.3794	91.9517
70	43.2752	45.4418	48.7576	51.7393	90.5312	95.0231	100.425	104.215
80	51.1720	53.5400	57.1532	60.3915	101.879	106.629	112.329	116.321
90	59.1963	61.7541	65.6466	69.1260	113.145	118.136	124.116	128.299
100	67.3276	70.0648	74.2219	77.9295	124.342	129,561	135.807	140.169

From "*Biometrika Tables for Statisticians*," Vol. 1, (3rd Edition) Cambridge University Press (1966); Edited by E. S. Pearson and H. O. Hartley.

TABLE 6.12. PERCENTAGE POINTS OF t DISTRIBUTIONS



	α					
d.f.	.25	.1	.05	.025	.01	.005
1	1.000	3.078	6.314	12.706	31.821	63.657
2	.816	1.886	2.920	4.303	6.965	9.925
3	.765	1.638	2.353	3.182	4.541	5.841
4	.741	1.533	2.132	2.776	3.747	4.604
5	.727	1.476	2.015	2.571	3.365	4.032
6	.718	1.440	1.943	2.447	3.143	3.707
7	.711	1.415	1.895	2.365	2.998	3.499
8	.706	1.397	1.860	2.306	2.896	3.355
9	.703	1.383	1.833	2.262	2.821	3.250
10	.700	1.372	1.812	2.228	2.764	3.169
11	.697	1.363	1.796	2.201	2.718	3.106
12	.695	1.356	1.782	2.179	2.681	3.055
13	.694	1.350	1.771	2.160	2.650	3.012
14	.692	1.345	1.761	2.145	2.624	2.977
15	.691	1.341	1.753	2.131	2.602	2.947
16	.690	1.337	1.746	2.120	2.583	2.921
17	.689	1.333	1.740	2.110	2.567	2.898
18	.688	1.330	1.734	2.101	2.552	2.878
19	.688	1.328	1.729	2.093	2.539	2.861
20	.687	1.325	1.725	2.086	2.528	2.845
21	.686	1.323	1.721	2.080	2.518	2.831
22	.686	1.321	1.717	2.074	2.508	2.819
23	.685	1.319	1.714	2.069	2.500	2.807
24	.685	1.318	1.711	2.064	2.492	2.797
25	.684	1.316	1.708	2.060	2.485	2.787
26	.684	1.315	1.706	2.056	2.479	2.779
27	.684	1.314	1.703	2.052	2.473	2.771
28	.683	1.313	1.701	2.048	2.467	2.763
29	.683	1.311	1.699	2.045	2.462	2.756
30	.683	1.310	1.697	2.042	2.457	2.750
40	.681	1.303	1.684	2.021	2.423	2.704
60	.679	1.296	1.671	2.000	2.390	2.660
120	.677	1.289	1.658	1.980	2.358	2.617
∞	.674	1.282	1.645	1.960	2.326	2.576

however, reduce the number of simulations substantially. Pertinent discussions are provided by Donigian et al. (1983), Carsel et al. (1984), and USDA (1980). Sensitivity testing assists in identifying the parameters that must be investigated to obtain a range of pesticide exposure.

The information required to describe the use of models in conducting exposure assessments is outside the intent of this manual. The use of models for conducting exposure assessments are described by Onishi et al., 1982; Mulkey and Falco (1983); and Donigian et al., 1985.

6.4 EXTRAPOLATION OF SITE SPECIFIC DATA TO OTHER FIELD SITES

Extrapolating observed field hydrologic and chemical characteristics data from site to site or region to region is possible. The development of this capability requires the assessment of paired field data. The requirements for these types of extrapolations are two-fold: (1) the distributions (e.g., standard deviation, coefficient of variation) of the hydrologic characteristics (soil, water, crop information) have to be known; (2) the distributions of necessary pesticide characteristics, such as soil/water distribution coefficient (K_p) and degradation rate also have to be known. Determination of these distributions will enable detailed sensitivity testing to be conducted to estimate the range, or distribution of runoff both from site-to-site and from year-to-year.

6.5 REFERENCES FOR SECTION 6

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APPENDIX A

Table A.1. USEFUL CONVERSION FACTORS FOR ENVIRONMENTAL DATA BASES

Temperature

°C = (°F - 32) (5/9)
°K = °C + 273
°R = °F + 460

Pressure

Psi	in.HG	atm	mmHg	bar	kg/cm^2	Newton/m^2
1	2.036	0.068	51.715	0.0689	0.0703	6894.8
0.491	1	0.033	25.40	0.0339	0.0345	3386.4
14.696	29.921	1	760.0	1.0132	1.033	101,325
0.0193	0.0393	0.0013	1	0.0013	0.0013	133.32
14.504	29.530	0.987	750.06	1	1.0197	1 x 10^5
14.223	28.959	0.968	735.56	0.9806	1	98,066
1.450x10^{-4}	2.953x10^{-4}	9.869x10-^{2}	0.0075	1x10^{-5}	1.0197x10^{-5}	1

Mass

lb$_m$	kg$_m$
1	0.454
2.205	1

Volume

in^3	ft^3	gal	liter	meter^3
1	5.787x10^{-4}	4.329x10^{-3}	0.0164	1.639x10^{-5}
1728	1	7.4806	28.317	0.0283
231.0	0.1337	1	3.785	0.00378
61.023	0.0353	0.2642	1	0.001
61023.7	35.315	264.17	1000.	1

Density

lb/ft^3	lb/gal	g/cm^3	kg/m^3 (g/liter)
1	0.1337	0.0160	16.018
7.4806	1	0.1198	119.827
62.428	8.345	1	10000.
0.624	0.0083	0.001	1

APPENDIX B

Table B.1. RANDOM UNIT TABLES*

Use of Table. If one wishes to select a random sample of N items from a universe of M items, the following procedure may be applied. (M > N.)

1. Decide upon some arbitrary scheme of selecting entries from the table. For example, one may decide to use the entries in the first line, second column; second line, third column; third line, fourth column; etc.

2. Assign numbers to each of the items in the universe from 1 to M. Thus, if M = 500, the items would be numbered from 001 to 500, and therefore, each designated item is associated with a three digit number.

3. Decide upon some arbitrary scheme of selecting positional digits from each entry chosen according to Step 1. Thus, if M = 500, one may decide to use the first, third, and fourth digit of each entry selected, and as a consequence a three digit number is created for each entry choice.

4. If the number formed is $\leq$ M, the correspondingly designated item in the universe is chosen for the random sample of N items. If a number formed is > M or is a repeated number of one already chosen, it is passed over and the next desirable number is taken. This process is continued until the random sample of N items is selected.

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*Handbook of tables for probability and statistics, second edition, W.H. Beyer (Ed.). Chemical Rubber Co., Cleveland, Ohio, 1974.

A TABLE OF 14,000 RANDOM UNITS

Line/Col.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
1	10480	15011	01536	02011	81647	91646	69179	14194	62590	36207	20969	99570	91291	90700
2	22368	46573	25595	85393	30995	89198	27982	53402	93965	34095	52666	19174	39615	99505
3	24130	48360	22527	97265	76393	64809	15179	24830	49340	32081	30680	19655	63348	58629
4	42167	93093	06243	61680	07856	16376	39440	53537	71341	57004	00849	74917	97758	16379
5	37570	39975	81837	16656	06121	91782	60468	81305	49684	60672	14110	06927	01263	54613
6	77921	06907	11008	42751	27756	53498	18602	70659	90655	15053	21916	81825	44394	42880
7	99562	72905	56420	69994	98872	31016	71194	18738	44013	48840	63213	21069	10634	12952
8	96301	91977	05463	07972	18876	20922	94595	56869	69014	60045	18425	84903	42508	32307
9	89579	14342	63661	10281	17453	18103	57740	84378	25331	12566	58678	44947	05585	56941
10	85475	36857	43342	53988	53060	59533	38867	62300	08158	17983	16439	11458	18593	64952
11	28918	69578	88231	33276	70997	79936	56865	05859	90106	31595	01547	85590	91610	78188
12	63553	40961	48235	03427	49626	69445	18663	72695	52180	20847	12234	90511	33703	90322
13	09429	93969	52636	92737	88974	33488	36320	17617	30015	08272	84115	27156	30613	74952
14	10365	61129	87529	85689	48237	52267	67689	93394	01511	26358	85104	20285	29975	89868
15	07119	97336	71048	08178	77233	13916	47564	81056	97735	85977	29372	74461	28551	90707
16	51085	12765	51821	51259	77452	16308	60756	92144	49442	53900	70960	63990	75601	40719
17	02368	21382	52404	60268	89368	19885	55322	44819	01188	65255	64835	44919	05944	55157
18	01011	54092	33362	94904	31273	04146	18594	29852	71585	85030	51132	01915	92747	64951
19	52162	53916	46369	58586	23216	14513	83149	98736	23495	64350	94738	17752	35156	35749
20	07056	97628	33787	09998	42698	06691	76988	13602	51851	46104	88916	19509	25625	58104
21	48663	91245	85828	14346	09172	30168	90229	04734	59193	22178	30421	61666	99904	32812
22	54164	58492	22421	74103	47070	25306	76468	26384	58151	06646	21524	15227	96909	44592
23	32639	32363	05597	24200	13363	38005	94342	28728	35806	06912	17012	64161	18296	22851
24	29334	27001	87637	87308	58731	00256	45834	15398	46557	41135	10367	07684	36188	18510
25	02488	33062	28834	07351	19731	92420	60952	61280	50001	67658	32586	86679	50720	94953
26	81525	72295	04839	96423	24878	82651	66566	14778	76797	14780	13300	87074	79666	95725
27	29676	20591	68086	26432	46901	20849	89768	81536	86645	12659	92259	57102	80428	25280
28	00742	57392	39064	66432	84673	40027	32832	61362	98947	96067	64760	64584	96096	98253
29	05366	04213	25669	26422	44407	44048	37937	63904	45766	66134	75470	66520	34693	90449
30	91921	26418	64117	94305	26766	25940	39972	22209	71500	64568	91402	42416	07844	69618
31	00582	04711	87917	77341	42206	35126	74087	99547	81817	42607	43808	76655	62028	76630
32	00725	69884	62797	56170	86324	88072	76222	36086	84637	93161	76038	65855	77919	88006
33	69011	65797	95876	55293	18988	27354	26575	08625	40801	59920	29841	80150	12777	48501
34	25976	57948	29888	88604	67917	48708	18912	82271	65424	69774	33611	54262	85963	03547
35	09763	83473	73577	12908	30883	18317	28290	35797	05998	41688	34952	37888	38917	88050
36	91567	42595	27958	30134	04024	86385	29880	99730	55536	84855	29080	09250	79656	73211
37	17955	56349	90999	49127	20044	59931	06115	20542	18059	02008	73708	83517	36103	42791
38	46503	18584	18845	49618	02304	51038	20655	58727	28168	15475	56942	53389	20562	87338
39	92157	89634	94824	78171	84610	82834	09922	25417	44137	48413	25555	21246	35509	20468
40	14577	62765	35605	81263	39667	47358	56873	56307	61607	49518	89656	20103	77490	18062
41	98427	07523	33362	64270	01638	92477	66969	98420	04880	45585	46565	04102	46880	45709
42	34914	63976	88720	82765	34476	17032	87589	40836	32427	70002	70663	88863	77775	69348
43	70060	28277	39475	46473	23219	53416	94970	25832	69975	94884	19661	72828	00102	66794
44	53976	54914	06990	67245	68350	82948	11398	42878	80287	88267	47363	46634	06541	97809
45	76072	29515	40980	07391	58745	25774	22987	80059	39911	96189	41151	14222	60697	59583
46	90725	52210	83974	29992	65831	38857	50490	83765	55657	14361	31720	57375	56228	41546
47	64364	67412	33339	31926	14883	24413	59744	92351	97473	89286	35931	04110	23726	51900
48	08962	00358	31662	25388	61642	34072	81249	35648	56891	69352	48373	45578	78547	81788
49	95012	68379	93526	70765	10592	04542	76463	54328	02349	17247	28865	14777	62730	92277
50	15664	10493	20492	38391	91132	21999	59516	81652	27195	48223	46751	22923	32261	85653

A TABLE OF 14,000 RANDOM UNITS

Line/Col.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
51	16408	81899	04153	53381	79401	21438	83035	92350	36693	31238	59649	91754	72772	02338
52	18629	81953	05520	91962	04739	13092	97662	24822	94730	06496	35090	04822	86772	98289
53	73115	35101	47498	87637	99016	71060	88824	71013	18735	20286	23153	72924	35165	43040
54	57491	16703	23167	49323	45021	33132	12544	41035	80780	45393	44812	12515	98931	91202
55	30405	83946	23792	14422	15059	45799	22716	19792	09983	74353	68668	30429	70735	25499
56	16631	35006	85900	98275	32388	52390	16815	69298	82732	38480	73817	32523	41961	44437
57	96773	20206	42559	78985	05300	22164	24369	54224	35083	19687	11052	91491	60383	19746
58	38935	64202	14349	82674	66523	44133	00697	35552	35970	19124	63318	29686	03387	59846
59	31624	76384	17403	53363	44167	64486	64758	75366	76554	31601	12614	33072	60332	92325
60	78919	19474	23632	27889	47914	02584	37680	20801	72152	39339	34806	08930	85001	87820
61	03931	33309	57047	74211	63445	17361	62825	39908	05607	91284	68833	25570	38818	46920
62	74426	33278	43972	10119	89917	15665	52872	73823	73144	88662	88970	74492	51805	99378
63	09066	00903	20795	95452	92648	45454	09552	88815	16553	51125	79375	97596	16296	66092
64	42238	12426	87025	14267	20979	04508	64535	31355	86064	29472	47689	05974	52468	16834
65	16153	08002	26504	41744	81959	65642	74240	56302	00033	67107	77510	70625	28725	34191
66	21457	40742	29820	96783	29400	21840	15035	34537	33310	06116	95240	15957	16572	06004
67	21581	57802	02050	89728	17937	37621	47075	42080	97403	48626	68995	43805	33386	21597
68	55612	78095	83197	33732	05810	24813	86902	60397	16489	03264	88525	42786	05269	92532
69	44657	66999	99324	51281	84463	60563	79312	93454	68876	25471	93911	25650	12682	73572
70	91340	84979	46949	81973	37949	61023	43997	15263	80644	43942	89203	71795	99533	50501
71	91227	21199	31935	27022	84067	05462	35216	14486	29891	68607	41867	14951	91696	85065
72	50001	38140	66321	19924	72163	09538	12151	06878	91903	18749	34405	56087	82790	70925
73	65390	05224	72958	28609	81406	39147	25549	48542	42627	45233	57202	94617	23772	07896
74	27504	96131	83944	41575	10573	08619	64482	73923	36152	05184	94142	25299	84387	34925
75	37169	94851	39117	89632	00959	16487	65536	49071	39782	17095	02330	74301	00275	48280
76	11508	70225	51111	38351	19444	66499	71945	05422	13442	78675	84081	66938	93654	59894
77	37449	30362	06694	54690	04052	53115	62757	95348	78662	11163	81651	50245	34971	52924
78	46515	70331	85922	38329	57015	15765	97161	17869	45349	61796	66345	81073	49106	79860
79	30986	81223	42416	58353	21532	30502	32305	86482	05174	07901	54339	58861	74818	46942
80	63798	64995	46583	09765	44160	78128	83991	42865	92520	83531	80377	35909	81250	54238
81	82486	84846	99254	67632	43218	50076	21361	64816	51202	88124	41870	52689	51275	83556
82	21885	32906	92431	09060	64297	51674	64126	62570	26123	05155	59194	52799	28225	85762
83	60336	98782	07408	53458	13564	59089	26445	29789	85205	41001	12535	12133	14645	23541
84	43937	46891	24010	25560	86355	33941	25786	54990	71899	15475	95434	98227	21824	19585
85	97656	63175	89303	16275	07100	92063	21942	18611	47348	20203	18534	03862	78095	50136
86	03299	01221	05418	38982	55758	92237	26759	86367	21216	98442	08303	56613	91511	75928
87	79626	06486	03574	17668	07785	76020	79924	25651	83325	88428	85076	72811	22717	50585
88	85636	68335	47539	03129	65651	11977	02510	26113	99447	68645	34327	15152	55230	93448
89	18039	14367	61337	06177	12143	46609	32989	74014	64708	00533	35398	58408	13261	47908
90	08362	15656	60627	36478	65648	16764	53412	09013	07832	41574	17639	82163	60859	75567
91	79556	29068	04142	16268	15387	12856	66227	38358	22478	73373	88732	09443	82558	05250
92	92608	82674	27072	32534	17075	27698	98204	63863	11951	34648	88022	56148	34925	57031
93	23982	25835	40055	67006	12293	02753	14827	22235	35071	99704	37543	11601	35503	85171
94	09915	96306	05908	97901	28395	14186	00821	80703	70426	75647	76310	88717	37890	40129
95	50937	33300	26695	62247	69927	76123	50842	43834	86654	70959	79725	93872	28117	19233
96	42488	78077	69652	61657	34136	79180	97526	43092	04098	73571	80799	76536	71255	64239
97	46764	86273	63003	93017	31204	36692	40202	35275	57306	55543	53203	18098	47625	88684
98	03237	45430	55417	63282	90816	17349	88298	90183	36600	78406	06216	95787	42579	90730
99	86591	81482	52667	61583	14972	90053	89534	76036	49199	43716	97548	04379	46370	28672
100	38534	01715	94964	87288	65680	43772	39560	12918	86537	62738	19636	51132	25739	56947

A TABLE OF 14,000 RANDOM UNITS

Line/Col.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
101	13284	16834	74151	92027	24670	36665	00770	22878	02179	51602	07270	76517	97275	45960
102	21224	00370	30420	03883	96648	89428	41583	17564	27395	63904	41548	49197	82277	24120
103	99052	47887	81085	64933	66279	80432	65793	83287	34142	13241	30590	97760	35848	91983
104	00199	50993	98603	38452	87890	94624	69721	57484	67501	77638	44331	11257	71131	11059
105	60578	06483	28733	37867	07936	98710	98539	27186	31237	80612	44488	97819	70401	95419
106	91240	18312	17441	01929	18163	69201	31211	54288	39296	37318	65724	90401	79017	62077
107	97458	14229	12063	59611	32249	90466	33216	19358	02591	54263	88449	01912	07436	50813
108	35249	38646	34475	72417	60514	69257	12489	51924	86871	92446	36607	11458	30440	52639
109	38980	46600	11759	11900	46743	27860	77940	39298	97838	95145	32378	68038	89351	37005
110	10750	52745	38749	87365	58959	53731	89295	59062	39404	13198	59960	70408	29812	83126
111	36247	27850	73958	20673	37800	63835	71051	84724	52492	22342	78071	17456	96104	18327
112	70994	66986	99744	72438	01174	42159	11392	20724	54322	36923	70009	23233	65438	59685
113	99638	94702	11463	18148	81386	80431	90628	52506	02016	85151	88598	47821	00265	82525
114	72055	15774	43857	99805	10419	76939	25993	03544	21560	83471	43989	90770	22965	44247
115	24038	65541	85788	55835	38835	59399	13790	35112	01324	39520	76210	22467	83275	32286
116	74976	14631	35908	28221	39470	91548	12854	30166	09073	75887	36782	00268	97121	57676
117	35553	71628	70189	26436	63407	91178	90348	55359	80392	41012	36270	77786	89578	21059
118	35676	12797	51434	82976	42010	26344	92920	92155	58807	54644	58581	95331	78629	73344
119	74815	67523	72985	23183	02446	63594	98924	20633	58842	85961	07648	70164	34994	67662
120	45246	88048	65173	50989	91060	89894	36063	32819	68559	99221	49475	50558	34698	71800
121	76509	47069	86378	41797	11910	49672	88575	97966	32466	10083	54728	81972	58975	30761
122	19689	90332	04315	21358	97248	11188	39062	63312	52496	07349	79178	33692	57352	72862
123	42751	35318	97513	61537	54955	08159	00337	80778	27507	95478	21252	12746	37554	97775
124	11946	22681	45045	13964	57517	59419	58045	44067	58716	58840	45557	96345	33271	53464
125	96518	48688	20996	11090	48396	57177	83867	86464	14342	21545	46717	72364	86954	55580
126	35726	58643	76869	84622	39098	36083	72505	92265	23107	60278	05822	46760	44294	07672
127	39737	42750	48968	70536	84864	64952	38404	94317	65402	13589	01055	79044	19308	83623
128	97025	66492	56177	04049	80312	48028	26408	43591	75528	65341	49044	95495	81256	53214
129	62814	08075	09788	56350	76787	51591	54509	49295	85830	59860	30883	89660	96142	18354
130	25578	22950	15227	83291	41737	79599	96191	71845	86899	70694	24290	01551	80092	82118
131	68763	69576	88991	49662	46704	63362	56625	00481	73323	91427	15264	06969	57048	54149
132	17900	00813	64361	60725	88974	61005	99709	30666	26451	11528	44323	34778	60342	60388
133	71944	60227	63551	71109	05624	43836	58254	26160	32116	63403	35404	57146	10909	07346
134	54684	93691	85132	64399	29182	44324	14491	55226	78793	34107	30374	48429	51376	09559
135	25946	27623	11258	65204	52832	50880	22273	05554	99521	73791	85744	29276	70326	60251
136	01353	39318	44961	44972	91766	90262	56073	06606	51826	18893	83448	31915	97764	75091
137	99083	88191	27662	99113	57174	35571	99884	13951	71057	53961	61448	74909	07322	80960
138	52021	45406	37945	75234	24327	86978	22644	87779	23753	99926	63898	54886	18051	96314
139	78755	47744	43776	83098	03225	14281	83637	55984	13300	52212	58781	14905	46502	04472
140	25282	69106	59180	16257	22810	43609	12224	25643	89884	31149	85423	32581	34374	70873
141	[illegible]	94202	02743	86847	79725	51811	12998	76844	05320	54236	53891	70226	38632	84776
142	[illegible]	13792	98190	01424	30078	28197	55583	05197	47714	68440	22016	79204	06862	94451
143	[illegible]	97912	68110	59812	95448	43244	31262	88880	13040	16458	43813	89416	42482	33939
144	[illegible]	75714	89585	99296	52640	46518	55486	90754	88932	19937	57119	23251	55619	23679
145	55322	07589	39600	60866	63007	20007	66819	84164	61131	81429	60676	42807	78286	29015
146	78017	90928	90220	92503	83375	26986	74399	30885	88567	29169	72816	53357	15428	86932
147	44768	43342	20696	26331	43140	69744	82928	24988	94237	46138	77426	39039	55596	12655
148	25100	19336	14605	86603	51680	97678	24261	02464	86563	74812	60069	71674	15478	47642
149	83612	46623	62876	85197	07824	91392	58317	37726	84628	42221	10268	20692	15699	29167
150	41347	81666	82961	60413	71020	83658	02415	33322	66036	98712	46795	16308	28413	05417

A TABLE OF 14,000 RANDOM UNITS

Line/Col.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
151	38128	51178	75096	13609	16110	73533	42564	59870	29399	67834	91055	89917	51096	89011
152	60950	00455	73254	96067	50717	13878	03216	78274	65863	37011	91283	33914	91303	49326
153	90524	17320	29832	96118	75792	25326	22940	24904	80523	38928	91374	55597	97567	38914
154	49897	18278	67160	39408	97056	43517	84426	59650	20247	19293	02019	14790	02852	05819
155	18494	99209	81060	19488	65596	59787	47939	91225	98768	43688	00438	05548	09443	82897
156	65373	72984	30171	37741	70203	94094	87261	30056	58124	70133	18936	02138	59372	09075
157	40653	12843	04213	70925	95360	55774	76439	61768	52817	81151	52188	31940	54273	49032
158	51638	22238	56344	44587	83231	50317	74541	07719	25472	41602	77318	15145	57515	07633
159	69742	99303	62578	83575	30337	07488	51941	84316	42067	49692	28616	29101	03013	73449
160	58012	74072	67488	74580	47992	69482	58624	17106	47538	13452	22620	24260	40155	74716
161	18348	19855	42887	08279	43206	47077	42637	45606	00011	20662	14642	49984	94509	56380
162	59614	09193	58064	29086	44385	45740	70752	05663	49081	26960	57454	99264	24142	74648
163	75688	28630	39210	52897	62748	72658	98059	67202	72789	01869	13496	14663	87645	89713
164	13941	77802	69101	70061	35460	34576	15412	81304	58757	35498	94830	75521	00603	97701
165	96656	86420	96475	86458	54463	96419	55417	41375	76886	19008	66877	35934	59801	00497
166	03363	82042	15942	14549	38324	87094	19069	67590	11087	68570	22591	65232	85915	91499
167	70366	08390	69155	25496	13240	57407	91407	49160	07379	34444	94567	66035	38918	65708
168	47870	36605	12927	16043	53257	93796	52721	73120	48025	76074	95605	67422	41646	14557
169	79504	77606	22761	30518	28373	73898	30550	76684	77366	32276	04690	61667	64798	66276
170	46967	74841	50923	15339	37755	98995	40162	89561	69199	42257	11647	47603	48779	97907
171	14558	50769	35444	59030	87516	48193	02945	00922	48189	04724	21263	20892	92955	90251
172	12440	25057	01132	38611	28135	68089	10954	10097	54243	06460	50856	65435	79377	53890
173	32293	29938	68653	10497	98919	46587	77701	99119	93165	67788	17638	23097	21468	36992
174	10640	21875	72462	77981	56550	55999	87310	69643	45124	00349	25748	00844	96831	30651
175	47615	23169	39571	56972	20628	21788	51736	33133	72696	32605	41569	76148	91544	21121
176	16948	11128	71624	72754	49084	96303	27830	45817	67867	18062	87453	17226	72904	71474
177	21258	61092	66634	70335	92448	17354	83432	49608	66520	06442	59664	20420	39201	69549
178	15072	48853	15178	30730	47481	48490	41436	25015	49932	20474	53821	51015	79841	32405
179	99154	57412	09858	65671	70655	71479	63520	31357	56968	06729	34465	70685	04184	25250
180	08759	61089	23706	32994	35426	36666	63988	98844	37533	08269	27021	45886	22835	78451
181	67323	57839	61114	62192	47547	58023	64630	34886	98777	75442	95592	06141	45096	73117
182	09255	13986	84834	20764	72206	89393	34548	93438	88730	61805	78955	18952	46436	58740
183	36304	74712	00374	10107	85061	69228	81969	92216	03568	39630	81869	52824	50937	27954
184	15884	67429	86612	47367	10242	44880	12060	44309	46629	55105	66793	93173	00480	13311
185	18745	32031	35303	08134	33925	03044	59929	95418	04917	57596	24878	61733	92834	64454
186	72934	40086	88292	65728	38300	42323	64068	98373	48971	09049	59943	36538	05976	82118
187	17626	02944	20910	57662	80181	38579	24580	90529	52303	50436	29401	57824	86039	81062
188	27117	61399	50967	41399	81636	16663	15634	79717	94696	59240	25543	97989	63306	90946
189	93995	18678	90012	63645	85701	85269	62263	68331	00389	72571	15210	20769	44686	96176
190	67392	89421	09623	80725	62620	84162	87368	29560	00519	84545	08004	24526	41252	14521
191	04910	12261	37566	80016	21245	69377	50420	85658	55263	68667	78770	04533	14513	18099
192	81453	20283	79929	59839	23875	13245	46808	74124	74703	35769	95588	21014	37078	39170
193	19480	75790	48539	23703	15537	48885	02861	86587	74539	65227	90799	58789	96257	02708
194	21456	13162	74608	81011	55512	07481	93551	72189	76261	91206	89941	15132	37738	59284
195	89406	20912	46189	76376	25538	87212	20748	12831	57166	35026	16817	79121	18929	40628
196	09866	07414	55977	16419	01101	69343	13305	94302	80703	57910	36933	57771	42546	03003
197	86541	24681	23421	13521	28000	94917	07423	57523	97234	63951	42876	46829	09781	58160
198	10414	96941	06205	72222	57167	83902	07460	69507	10600	08858	07685	44472	64220	27040
199	49942	06683	41479	58982	56288	42853	92196	20632	62045	78812	35895	51851	83534	10689
200	23995	68882	42291	23374	24209	27024	67460	94783	40937	16961	26053	78749	46704	21983

APPENDIX C. STUDENT'S t-DISTRIBUTION (Chemical Rubber Co., 1974*)

PERCENTAGE POINTS, STUDENTS *t*-DISTRIBUTION

$$F(t) = \int_{-\infty}^{t} \frac{\Gamma\left(\frac{n+1}{2}\right)}{\sqrt{n\pi}\,\Gamma\left(\frac{n}{2}\right)} \left(1 + \frac{x^2}{n}\right)^{-\frac{n+1}{2}} dx$$

n \ F	.60	.75	.90	.95	.975	.99	.995	.9995
1	.325	1.000	3.078	6.314	12.706	31.821	63.657	636.619
2	.289	.816	1.886	2.920	4.303	6.965	9.925	31.598
3	.277	.765	1.638	2.353	3.182	4.541	5.841	12.924
4	.271	.741	1.533	2.132	2.776	3.747	4.604	8.610
5	.267	.727	1.476	2.015	2.571	3.365	4.032	6.869
6	.265	.718	1.440	1.943	2.447	3.143	3.707	5.959
7	.263	.711	1.415	1.895	2.365	2.998	3.499	5.408
8	.262	.706	1.397	1.860	2.306	2.896	3.355	5.041
9	.261	.703	1.383	1.833	2.262	2.821	3.250	4.781
10	.260	.700	1.372	1.812	2.228	2.764	3.169	4.587
11	.260	.697	1.363	1.796	2.201	2.718	3.106	4.437
12	.259	.695	1.356	1.782	2.179	2.681	3.055	4.318
13	.259	.694	1.350	1.771	2.160	2.650	3.012	4.221
14	.258	.692	1.345	1.761	2.145	2.624	2.977	4.140
15	.258	.691	1.341	1.753	2.131	2.602	2.947	4.073
16	.258	.690	1.337	1.746	2.120	2.583	2.921	4.015
17	.257	.689	1.333	1.740	2.110	2.567	2.898	3.965
18	.257	.688	1.330	1.734	2.101	2.552	2.878	3.922
19	.257	.688	1.328	1.729	2.093	2.539	2.861	3.883
20	.257	.687	1.325	1.725	2.086	2.528	2.845	3.850
21	.257	.686	1.323	1.721	2.080	2.518	2.831	3.819
22	.256	.686	1.321	1.717	2.074	2.508	2.819	3.792
23	.256	.685	1.319	1.714	2.069	2.500	2.807	3.767
24	.256	.685	1.318	1.711	2.064	2.492	2.797	3.745
25	.256	.684	1.316	1.708	2.060	2.485	2.787	3.725
26	.256	.684	1.315	1.706	2.056	2.479	2.779	3.707
27	.256	.684	1.314	1.703	2.052	2.473	2.771	3.690
28	.256	.683	1.313	1.701	2.048	2.467	2.763	3.674
29	.256	.683	1.311	1.699	2.045	2.462	2.756	3.659
30	.256	.683	1.310	1.697	2.042	2.457	2.750	3.646
40	.255	.681	1.303	1.684	2.021	2.423	2.704	3.551
60	.254	.679	1.296	1.671	2.000	2.390	2.660	3.460
120	.254	.677	1.289	1.658	1.980	2.358	2.617	3.373
∞	.253	.674	1.282	1.645	1.960	2.326	2.576	3.291

*Handbook of tables for probability and statistics, second edition, W.H. Beyer, Ed. Chemical Rubber Company, Cleveland, Ohio. 1974.

APPENDIX D: SOIL NAMES AND HYDROLOGIC CLASSIFICATIONS[1,2]

AABERG	C	ADAMSON	B	AHL	C	ALDAX	D	ALMY	B
AASTAD	B	ADAMSTOWN		AHLSTROM	C	ALDEN	D	ALOHA	C
ABAC	D	ADAMSVILLE	C	AHMEEK	B	ALDER	B	ALONSD	B
ABAJO	C	ADATON	D	AHOLT	D	ALDERDALE	C	ALOVAR	C
ABBOTT	D	ADAVEN	D	ANTANUM	C	ALDERWOOD	C	ALPENA	B
ABBOTTSTOWN	C	ADDIELOU	C	AHWAHNEE	C	ALDINO	C	ALPHA	C
ABCAL	D	ADDISON	D	AIBONITO	C	ALDWELL	C	ALPUN	B
ABEGG	B	ADDY	C	AIKEN	B/C	ALEKNAGIK	B	ALPOWA	B
ABELA	B	ADE	A	AIKMAN	D	ALEMEDA	C	ALPS	C
ABELL	B	ADEL	A	AILEY	B	ALEX	B	ALSEA	B
ABERDEEN	D	ADELAIDE	D	AINAKEA	B	ALEXANDRIA	C	ALSPAUGH	C
ABES	D	ADELANTO	B	AIRMONT	C	ALEXIS	B	ALSTAD	B
ABILENE	C	ADELINO	B	AIROTSA	B	ALFORD	B	ALSTOWN	B
ABINGTON	B	ADELPHIA	C	AIRPORT	D	ALGANSEE	B	ALTAMONT	D
ABIQUA	C	ADENA	C	AITS	B	ALGERITA	B	ALTAVISTA	C
ABO	B/C	ADGER	D	AJO	C	ALGIERS	C/D	ALTDORF	D
ABOR	D	ADILIS	A	AKAKA	A	ALGOMA	B/D	ALTMAR	B
ABRA	C	ADIRONDACK		AKASKA	B	ALHAMBRA	B	ALTO	C
ABRAHAM	B	ADIV	B	AKELA	C	ALICE	A	ALTOGA	C
ABSAROKEE	C	ADJUNTAS	C	ALADDIN	B	ALICEL	BV	ALTON	B
ABSCOTA	B	ADKINS	B	ALAE	A	ALICIA	B	ALTUS	B
ABSHER	D	ADLER	C	ALAELOA	B	ALIDA	B	ALTVAN	B
ABSTED	D	ADOLPH	D	ALAGA	A	ALIKCHI	B	ALUM	B
ACACIO	C	ADRIAN	A/D	ALAKAI	D	ALINE	A	ALUSA	D
ACADEMY	C	AENEAS	B	ALAMA	B	ALKO	D	ALVIN	B
ACADIA	D	AETNA	B	ALAMANCE	B	ALLAGASH	B	ALVIRA	C
ACANA	D	AFTON	D	ALAMO	D	ALLARD	B	ALVISO	D
ACASCO	D	AGAR	B	ALAMOSA	C	ALLEGHENY	B	ALVOR	C
ACEITUNAS	B	AGASSIZ	D	ALAPAHA	D	ALLEMANDS	D	AMADOR	D
ACEL	D	AGATE	D	ALAPAI	A	ALLEN	B	AMAGON	D
ACKER	B	AGAWAM	B	ALBAN	B	ALLENDALE	C	AMALU	D
ACKMEN	B	AGENCY	C	ALBANO	D	ALLENS PARK	B	AMANA	B
ACME	C	AGER	D	ALBANY	C	ALLENSVILLE	C	AMARGOSA	D
ACO	B	AGNER	B	ALBATON	D	ALLENTINE	D	AMARILLO	B
ACOLITA	B	AGNEW	B/C	ALBEE	C	ALLENWOOD	B	AMASA	B
ACOMA	C	AGNOS	B	ALBEMARLE	B	ALLESSIO	B	AMBERSON	
ACOVE	C	AGUA	B	ALBERTVILLE	C	ALLEY	C	AMBOY	C
ACREE	C	AGUADILLA	A	ALBIA	C	ALLIANCE	B	AMBRAW	C
ACRELANE	C	AGUA DULCE	C	ALBION	B	ALLIGATOR	D	AMEDEE	A
ACTON	B	AGUA FRIA	B	ALBRIGHTS	C	ALLIS	D	AMELIA	B
ACUFF	B	AGUALT	B	ALCALDE	C	ALLISON	C	AMENIA	B
ASWORTH	B	AGUEDA	B	ALCESTER	B	ALLOUEZ	C	AMERICUS	A
ACY	C	AGUILITA	B	ALCOA	B	ALLOWAY		AMES	C
ADA	B	AGUIRRE	D	ALCONA	B	ALMAC	B	AMESHA	B
ADAIR	D	AGUSTIN	B	ALCOVA	B	ALMENA	C	AMHERST	C
ADAMS	A	AHATONE	D	ALDA	C	ALMONT	D	AMITY	C

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[1] Soil Conservation Service. 1972. Hydrology. Section 4, SCS National Engineering Handbook. U.S. Department of Agriculture, Washington DC. NEH-Notice 4-102.

[2] NOTE: A blank hydrologic group indicates the soil group has not been determined. Two soil groups such as B/C indicates the drained/undrained situation.

AMMON	B
AMOLE	C
AMOR	B
AMOS	C
AMSDEN	B
AMSTERDAM	B
AMTOFT	D
AMY	D
ANACAPA	B
ANAHUAC	D
ANAMITE	D
ANAPRA	B
ANASAZI	B
ANATONE	D
ANAVERDE	B
ANAWALT	D
ANCHO	B
ANCHORAGE	A
ANCHOR BAY	D
ANCHOR POINT	D
ANCLOTE	D
ANCO	C
ANDERLY	C
ANDERS	C
ADERSON	B
ANDES	C
ANDORINIA	C
ANDOVER	D
ANDREEN	B
ANDREESON	C
ANDRES	B
ANDRES	C
ANED	D
ANETH	A
ANGELICA	D
ANGELINA	B/D
ANGELO	C
ANGIE	C
ANGLE	A
ANGLEN	B
ANGOLA	C
ANGOSTORA	B
ANHALT	D
ANIAK	D
ANITA	D
ANKENY	A
ANLAUF	C
ANNABELLA	B
ANNANDALE	C
ANNISTON	C
ANGXA	A
ANONES	C
ANSARI	D
ANSEL	B
ANSELMO	A
ANSON	B
ANTELOPE SP	C
ANTERO	C
ANT FLAT	C
ANTHO	B
ANTHONY	B
ANTIGO	B
ANTILON	B
ANTIOCH	D
ANTLER	C
ANTOINE	C
ANTROBUS	B
ANTY	B
ANVIK	B
ANWAY	B
ANZA	B
ANZIANO	C
APACHE	D
APAXUIE	A
APISHAPA	C
APISON	B
APOPKA	A
APPIAN	C
APPLEGATE	C
APPLETON	C
APPLING	B
APRON	B
APT	C
APTAKISIC	B
ARABY	
ARADA	C
ARANSAS	D
ARAPIEN	C
ARAVE	O
ARAVETON	B
ARBELA	O
ARBONE	B
ARBOR	B
ARBUCKLE	B
ARCATA	B
ARCH	B
ARCHABAL	B
ARCHER	C
ARCHIN	C
ARCO	B
ARCOLA	C
ARD	C
ARDEN	B
ARDENVOIR	B
ARDILLA	C
AREDALE	B
ARENA	C
ARENALES	
ARENDTSVILLE	B
ARENOSA	A
ARENZVILLE	B
ARGONAUT	D
ARGUELLO	B
ARGYLE	B
ARIEL	C
ARIZO	A
ARKABUTLA	C
ARKPORT	B
ARLAND	B
ARLE	B
ARLING	D
ARLINGTON	C
ARLOVAL	C
ARMAGH	D
ARMIJO	D
ARMINGTON	D
ARMO	B
ARMOUR	B
ARMSTER	C
ARMSTRONG	D
ARMJOHEE	D
ARNEGARD	B
ARNHART	C
ARNHEIM	C
ARNO	D
ARNOLD	B
ARNOT	C/D
ARNY	A
AROOSTOOK	
ARDSA	C
ARP	C
ARRINGTON	B
ARRITOLA	D
ARROLIME	C
ARRON	D
ARROW	B
ARROWSMITH	B
ARROYO SECO	B
ARTA	C
ARTOIS	C
ARVADA	D
ARVANA	C
ARVESON	D
ARVILLA	B
ARZELL	C
ASA	B
ASBURY	B
ASCALON	B
ASCHOFF	B
ASHBY	C
ASHCROFT	B
ASHDALE	B
ASHE	B
ASHKUM	C
ASHLAR	B
ASHLEY	A
ASH SPRINGS	C
ASHTON	B
ASHUE	B
ASHUELOT	C
ASHWOOD	C
ASKEW	C
ASO	C
ASOTIN	C
ASPEN	B
ASPERMONT	B
ASSINNIBOINE	B
ASSUMPTION	B
ASTATULA	A
ASTOR	A/D
ASTORIA	B
ATASCADERO	C
ATASCOSA	D
ATCO	B
ATENCIO	B
ATEPIC	D
ATHELWOLL	B
ATHENA	B
ATHENS	B
ATHERLY	B
ATHERTON	B/D
ATHMAR	C
ATHOL	B
ATKINSON	B
ATLAS	D
ATLEE	C
ATMORE	B/D
ATOKA	C
ATON	B
ATRYPA	C
ATSION	C
ATTERBERRY	B
ATTEWAN	A
ATTICA	B
ATTLEBORO	
ATWATER	B
ATWELL	C/D
ATWOOD	B
AUBBEENAUBBEE	B
AUBERRY	B
AUBURN	C/D
AUBURNDALE	D
AUDIAN	B
AU GRES	C
AUGSBURG	B
AUGUSTA	C
AULD	D
AURA	B
AURORA	C
AUSTIN	C
AUSTWELL	D
AUXVASSE	D
AUZQUI	B
AVA	C
AVALANCHE	B
AVALON	B
AVERY	B
AVON	C
AVONBURG	D
AVONDALE	E
AWBREY	D
AXTELL	D
AYAR	D
AYCOCK	B
AYON	B
AYR	B
AYRES	D
AYRSHIRE	C
AYSEES	B
AZAAR	C
AZARMAN	C
AZELTINE	B
AZFIELD	B
AZTALAN	B
AZTEC	B
AZULE	C
AZWELL	B
BABB	A
BABBINGTON	B
BABCOCK	C
BABYLON	A
BACA	C
BACH	D
BACHUS	C
BACKBONE	A
BACULAN	A
BADENAUGH	B
BADGER	C
BADGERTON	B
BADO	D
BADUS	C
BAGARD	C
BAGDAD	B
BAGGOTT	D
BAGLEY	B
BAHEM	B
BAILE	D
BAINVILLE	C
BAIRD HOLLOW	C
BAJURA	D
BAKEOVEN	D
BAKER	D
BAKER PASS	D
BALAAM	A
BALCH	D
BALCOM	B
BALD	C
BALDER	C
BALDOCK	B/C
BALDWIN	D
BALDY	B
BALE	C
BALLARD	B
BALLER	D
BALLINGER	C
BALM	B/C
BALMAN	B/C
BALON	B
BALTIC	D
BALTIMORE	B
BALTO	D
BAMBER	B
BAMFORTH	B
BANCAS	B
BANCROFT	B
BANDERA	B
BANGO	C
BANGOR	B
BANGSTON	A
BANKARD	A
BANKS	A
BANNER	C
BANNERVILLE	C/D
BANNOCK	B
BANQUETE	D
BARABOO	B
BARAGA	C
BARBARY	D
BARBOUR	B
BARBOURVILLE	B
BARCLAY	C
BARCO	B
BARCUS	B
BARD	D
BARDEN	C
BARDLEY	C
BARELA	C
BARFIELD	D
BARFUSS	B
BARGE	C
BARISHMAN	C
BARKER	C
BARKERVILLE	C
BARKLEY	B
BARLANE	D
BARLING	C
BARLOW	B
BARNARD	D
BARNES	B
BARNESTON	B
BARNEY	A
BARNHARDT	B
BARNSTEAD	
BARNUM	B
BARRADA	D
BARRETT	D
BARRINGTON	B
BARRON	B
BARRONETT	C

BARROWS	D
BARRY	D
BARSTOW	B
BARTH	C
BARTINE	C
BARTLE	D
BARTLEY	C
BARTON	B
BARTONFLAT	B
BARVON	C
BASCOM	B
BASEHOR	D
BASHAW	D
BASHER	B
BASILE	D
BASIN	C
BASINGER	C
BASKET	C
BASS	A
BASSEL	B
BASSETT	B
BASSFIELD	B
BASSLER	D
BASTIAN	D
BASTROP	B
BATA	A
BATAVIA	B
BATES	B
BATH	C
BATTERSON	D
BATTLE CREEK	C
BATZA	D
BAUDETTE	B
BAUER	C
BAUGH	B/C
BAXTER	B
BAXTERVILLE	B
BAYAMON	B
BAYARD	A
BAYBORO	D
BAYERTON	C
BAYLOR	D
BAYSHORE	B/C
BAYSIDE	C
BVAYUCOS	D
BAYWOOD	A
BAZETTE	C
BAZILE	B
BEAD	C
BEADLE	C
BEALES	A
BEAR BASIN	B
BEAR CREEK	C
BEARDALL	C
BEARDEN	C
BEARDSTOWN	C
BEAR LAKE	D
BEARMOUTH	A
BEARPAW	B
BEAR PRAIRIE	B
BEARSKIN	D
BEASLEY	C
BEASON	C
BEATON	C
BEATTY	C
BEAUCOUP	B
BEAUFORD	D
BEAUMONT	D
BEAUREGARD	C
BEAUSITE	B
BEAUVAIS	B
BEAVERTON	A
BECK	C
BECKER	B
BECKET	C
BECKLEY	B
BECKTON	D
BECKWITH	C
BECKWOURTH	B
BECREEK	B
BEDFORD	C
BEDINGTON	B
BEDNER	C
BEEBE	A
BEECHER	C
BEECHY	
BEEHIVE	B
BEEK	C
BEENOM	D
BEEZAR	B
BEGAY	B
BEGOSHIAN	C
BEHANIN	B
BEHEMOTOSH	B
BEHRING	D
BEIRMAN	D
BEJUCOS	B
BELCHER	D
BELDEN	D
BELDING	B
BELEN	C
BELFAST	B
BELFIELD	B
BELFORE	B
BELGRADE	B
BELINDA	D
BELKNAP	C
BELLAMY	C
BELLAVISTA	D
BELLE	B
BELLEFONTAINE	
BELLICUM	B
BELLINGHAM	C
BELLPINE	C
BELMONT	B
BELMORE	B
BELT	D
BELTED	D
BELTON	C
BELTRAMI	B
BELTSVILLE	C
BELUGA	D
BELVOIR	C
BENCLARE	C
BENEVOLA	C
BENEWAH	C
BENFIRLD	C
BENGE	B
BEN HUR	B
BENIN	D
BENITO	D
BENJAMIN	D
BEN LOMOND	B
BENMAN	A
BENNDALE	B
BENNETT	C
BENNINGTON	D
BENOIT	D
BENSON	C/D
BETNTEEN	B
BENTONVILLE	C
BENZ	D
BEOTIA	B
BEOWAWE	D
BERCAIL	C
BERDA	B
BEREA	C
BERENICETON	B
BERENT	A
BERGLAND	D
BERGSTROM	B
BERINO	B
BERKELEY	
BERKS	C
BERKSHIRE	B
BERLIN	C
BERMESA	C
BERMUDIAN	B
BERNAL	D
BERNALDO	B
BERNARD	D
BERNARDINO	C
BERNARDSTON	C
BERNHILL	B
BERNICE	A
BERNING	C
BERRENDOS	D
BERRYLAND	D
BERTELSON	B
BERTHOUD	B
BERTIE	C
BERTOLOTTI	B
BERTRAND	B
BERVILLE	D
BERYL	B
BESSEMER	B
BETHANY	C
BETHEL	D
BETTERAVIA	C
BETTS	B
BEULAH	B
BEVENT	B
BEVERLY	B
BEW	D
BEWLEYVILLE	B
BEWLIN	D
BEXAR	C
BEZZANT	B
BIBB	B/D
BIBON	A
BICKELTON	B
BICKLETON	C
BICKMORE	C
BICONDOA	C
BIDDEFORD	D
BIDDLEMAN	C
BIDMAN	C
BIDWELL	B
BIEBER	D
BIENVILLE	A
BIG BLUE	D
BIGEL	A
BIGELOW	C
BIGETTY	C
BIGGS	A
BIGGSVILLE	B
BIG HORN	C
BIGNELL	B
BIG TIMBER	D
BIGWIN	D
BIJOU	A
BILLETT	A
BILLINGS	C
BINDLE	B
BINFORD	B
BINGHAM	B
BINNSVILLE	D
BINS	B
BINTON	C
BIPPUS	B
BIRCH	A
BIRCHWOOD	C
BIRDOW	B
BIRDS	C
BIRDSALL	D
BIRDSBORO	B
BIRDSLEY	D
BIRKBECK	B
BISBEE	A
BISCAY	C
BISHOP	B/C
BISPING	B
BISSELL	B
BISTI	C
BIT	D
BITTERON	A
BITTERROOT	C
BITTER SPRING	C
BITTON	B
BIXBY	B
BJORK	C
BLANCHLY	C
BLACKBURN	B
BLACK BUTTE	C
BLACK CANYON	D
BLACKCAP	A
BLACKETT	B
BLACKFOOT	B/C
BLACKHALL	D
BLACKHAWK	D
BLACKLEAF	B
BLACKLEED	A
BLACKLUCK	D
BLACKMAN	C
BLACK MOUNTAIN	D
BLACKOAR	C
BLACKPIPE	C
BLACK RIDGE	D
BLACKROCK	B
BLACKSTON	B
BLACKTAIL	B
BLACKWATER	D
BLACKWELL	B/D
BLADEN	D
BLAGO	D
BLAINE	B
BLAIR	C
BLAIRTON	C
BLAKE	C
BLAKELAND	A
BLAKENEY	C
BLAKEPORT	B
BLALOCK	D
BLAMER	C
BLANCA	B
BLANCHARD	A
BLANCHESTER	B/D
BLAND	C
BLANDFORD	C
BLANDING	B
BLANEY	B
BLANKET	C
BLANTON	A
BLANYON	C
BLASDELL	A
BLASINGAME	C
BLAZON	D
BLENCOE	C
BLEND	D
BLENDON	B
BLETHEN	B
BLEVINS	B
BLEVINTON	B/D
BLIOHTON	D
BLISS	D
BLOCKTON	C
BLODGETT	A
BLOMFORD	B
BLOOM	C
BLOOMFIELD	A
BLOOMING	B
BLOOK	D
BLOSSOM	C
BLOUNT	C
BLOUNTVILLE	C
BLUCHER	C
BLUEBELL	C
BLUE EARTH	D
BLUEJOINT	B
BLUE LAKE	A
BLUEPOINT	B
BLUE STAR	B
BLUEWING	B
BLUFFDALE	C
BLUFFTON	D
BLUFORD	D
BLY	B
BLYTHE	D
BOARDTREE	C
BOBS	D
BOBTAIL	B
BOCK	B
BODELL	D
BODENBURG	B
BODINE	B
BOEL	A
BOELUS	A
BOESEL	B
BOETTCHER	C
BOGAN	C
BOGART	B
BOGUE	D
BOHANNON	C
BOHEMIAN	B
BOISTFORT	C
BOLAR	C
BOLD	B
BOLES	C
BOLIVAR	B
BOLIVIA	B

BOLTON	B
BOMDAY	B
BON	B
BONACCORD	D
BONAPARTE	A
BOND	D
BONDRANCH	D
BONDURANT	B
BONHAM	C
BONIFAY	A
BONILLA	B
BONITA	D
BONN	D
BONNER	B
BONNET	B
BONNEVILLE	B
BONNICK	A
BONNIE	D
BONO	D
BONSALL	D
BONTA	C
BONTI	C
BOOKER	D
BOOMER	B
BOONE	A
BOONESBORO	B
BOONTON	C
BOOTH	C
BORACHO	C
BORAH	A/C
BORDA	D
BORDEAUX	B
BORDEN	B
BORDER	B
BORNSTEDT	C
BORREGO	C
BORUP	B
BORVANT	D
BORZA	C
BOSANKO	D
BOSCO	B
BOSKET	B
BOSLER	B
BOSQUE	B
BOSS	D
BOSTON	C
BOSTWICK	B
BOSWELL	D
BOSWORTH	D
BOTELLA	B
BOTHWELL	C
BOTTINEAU	C
BOTTLE	A
BOULDER	B
BOULDER LAKE	D
BOULDER POINT	B
BOULFLAT	D
BOURNE	C
BOW	C
BOWBAC	C
BOWBELLS	B
BOWDOIN	D
BOWDRE	C
BOWERS	C
BOWIE	B
BOWMAN	B/D
BOWMANSVILLE	C
BOXELDER	C
BOXWELL	C
BOY	A
BOYCE	B/D
BOYD	D
BOYER	B
BOYNTON	
BOYSAG	D
BOYSEN	D
BOZARTH	C
BOZE	B
BOZEMAN	A
BRACEVILLE	C
BRACKEN	D
BRACKETT	C
BRAD	D
BRADDOCK	C
BRADENTON	B/D
BRADER	D
BRADFORD	B
BRADSHAW	B
BRADWAY	D
BRADY	B
BRADYVILLE	C
BRAHAM	B
BRAINERD	B
BRALLIER	D
BRAM	B
BRAMARD	B
BRAMBLE	C
BRAMWELL	C
BRAND	D
BRANDENBURG	A
BRANDON	B
BRANDYWINE	C
BRANFORD	B
BRANTFORD	B
BRANYON	D
BRASHEAR	C
BRASSFIELD	B
BRATTON	B
BRAVANE	D
BRAXTON	C
BRAYMILL	B/D
BRAYS	D
BRAYTON	V
BRAZITO	A
BRAZOS	A
BREA	B
BRECKENRIDGE	D
BRECKNOCK	B
BREECE	B
BREGAR	D
BREMEN	B
BREMER	B
BREMO	C
BREMS	A
BRENDA	C
BRENNAN	B
BRENNER	C/D
BRENT	C
BRENTON	B
BRENTWOOD	B
BRESSER	B
BREVARD	B
BREVORT	B
BREWER	C
BREWSTER	D
BREWTON	C
BRICKEL	C
BRICKTON	C
BRIDGE	C
BRIDGEHAMPTON	B
BRIDGEPORT	B
BRIDGER	A
BRIDGESON	B/C
BRIDGET	B
BRIDGEVILLE	B
BRIDGPORT	B
BRIEDWELL	B
BRIEF	B
BRIENSBURG	
BRIGGS	A
BRIGGSDALE	C
BRIGGSVILLE	C
BRIGHTON	A/D
BRIGHTWOOD	C
BRILL	B
BRIM	C
BRIMFIELD	C/D
BRIMLEY	B
BRINEGAR	B
BRINKERT	C
BRINKERTON	D
BRISCOT	B
BRITE	C
BRITTON	C
BRIZAM	A
BROAD	C
BROADALBIN	C
BROADAX	B
BROADBROOK	C
BROAD CANYON	B
BROADHEAD	C
BROADHURST	D
BROCK	D
BROCKLISS	C
BROCKMAN	C
BROCKO	B
BROCKPORT	D
BROCKTON	D
BROCKWAY	B
BRODY	C
BROE	B
BROGAN	B
BROGDON	B
BROLLIAR	D
BROMO	B
BRONAUGH	B
BRONCHO	B
BRONSON	B
BRONTE	C
BROOKE	C
BROOKFIELD	B
BROOKINGS	B
BROOKLYN	D
BROOKSIDE	C
BROOKSTON	B/D
BROOKSVILLE	D
BROOMFIELD	D
BROSELEY	B
BROSS	B
BROUGHTON	D
BROWARD	C
BROWNELL	B
BROWNFIELD	A
BROWNLEE	B
BROYLES	B
BRUCE	D
BRUFFY	C
BRUIN	C
BRUNEEL	B/C
BRUNO	A
BRUNT	C
BRUSH	
BRUSSETT	B
BRYAN	A
BRYCAN	B
BRYCE	D
BUCAN	D
BUCHANAN	C
BUCHENAU	C
BUCHER	C
BUCKHOUSE	A
BUCKINGHAM	
BUCKLAND	C
BUCKLEBAR	B
BUCKLEY	B/C
BUCKLON	D
BUCKNER	A
BUCKNEY	A
BUCKS	B
BUCKSKIN	C
BUCODA	C
BUDD	B
BUDE	C
BUELL	B
BUENA VISTA	B
BUFFINGTON	B
BUFFMEYER	B
BUFF PEAK	C
BUICK	C
BUIST	B
BUKREEK	B
BULLION	D
BULLREY	B
BULL RUN	B
BULL TRAIL	B
BULLY	B
BUMGARD	B
BUNCOMBE	A
BUNDO	B.
BUNDYMAN	C
BUNEJUG	C
BUNDER	D
BUNSELMEIER	C
BUNTINGVILLE	B/C
BUNYAN	B
BURBANK	A
BURCH	B
BURCHARD	B
BURCHELL	B/C
BURDETT	C
BUREN	C
BURGESS	C
BURGI	B
BURGIN	D
BURKE	C
BURKHARDT	B
BURLEIGH	D
BURLESON	D
BURLINGTON	A
BURMA	
BURMESTER	D
BURNAC	C
BURNETTE	B
BURNHAM	D
BURNSIDE	B
BURNSVILLE	B
BURNT LAKE	B
BURRIS	D
BURT	D
BURTON	B
BUSE	B
BUSH	B
BUSHNELL	C
BUSHVALLEY	D
BUSTER	C
BURANO	C
BUTLER	D
BUTLERTOWN	C
BUTTE	C
BUTTERFIELD	C
BUTTON	C
BUXIN	D
BUXTON	C
BYARS	D
BYNUM	C
BYRON	A
CABALLO	B
CABARTON	D
CABBA	C
CABBART	D
CABEZON	D
CABIN	C
CABINET	C
CABLE	D
CABO ROJO	C
CABOT	D
CACAPON	B
CACHE	D
CACIQUE	C
CADDO	D
CADEVILLE	D
CADMUS	B
CADOMA	D
CADOR	C
CAGEY	C
CAGUABO	D
CAGWIN	B
CAHABA	B
CAHILL	B
CAHONE	C
CAHTO	C
CAID	B
CAIRO	D
CAJALCO	C
CAJON	A
CALABAR	D
CALABASAS	B
CALAIS	C
CALAMINE	D
CALAPOOYA	C
CALAWAH	B
CALCO	C
CALDER	D
CALDWELL	B
CALEAST	C
CALEB	B
CALERA	C
CALHI	A
CALHOUN	D

CALICO	D
CALIFON	C
CALIMUS	BV
CALITA	B
CALIZA	B
CALKINS	C
CALLABO	C
CALLAHAN	C
CALLEGUAS	D
CALLINGS	C
CALLOWAY	C
CAIMAR	B
CALNEVA	C
CALOUSE	B
CALPINE	B
CALVERT	D
CALVERTON	C
CALVIN	C
CALVISTA	D
CAM	B
CAMAGUEY	D
CAMARGO	B
CAMARILLO	B/C
CAMAS	A
CAMAS CREEK	B/D
CAMBERN	C
CAMBRIDGE	C
CAMDEN	B
CAMERON	D
CAMILLUS	B
CAMP	B
CAMPBELL	B/C
CAMPHORA	B
CAMPIA	B
CAMPO	C
CAMPONE	B/C
CAMPSPASS	C
CAMPUS	B
CAMRODEN	C
CANA	C
CANAAN	C/D
CANADIAN	B
CANADICE	D
CANANDAIGUA	D
CANASERAGA	C
CANAVERAL	C
CANBURN	D
CANDELERO	C
CANE	C
CANEADEA	D
CANEEK	B
CANEL	B
CANELO	D
CANEY	C
CANEYVILLE	C
CANEZ	B
CANFIELD	C
CANISTED	C
CANNINGER	D
CANNON	B
CANOE	B
CANONCITO	B
CANOVA	B/D
CANTALA	B
CANTON	B
CANTRIL	B
CANTUA	B
CANUTIO	B
CANYON	D
CAPAC	B
CAPAY	D
CAPE	D
CAPE FEAR	D
CAPERS	D
CAPILLO	C
CAPLES	C
CAPPS	B
CAPSHAW	C
CAPULIN	B
CAPUTA	C
CARACO	C
CARALAMPI	B
CARBO	C
CARBOL	D
CARBONDALE	D
CARBURY	B
CARCITY	D
CARDIFF	B
CARDINGTON	C
CARDON	D
CAREY	B
CAREY LAKE	B
CAREYTOWN	D
CARGILL	C
CARIBE	B
CARIBEL	B
CARIBOU	B
CARLIN	D
CARLINTON	B
CARLISLE	A/D
CARLOTTA	B
CARLOW	D
CARLSBAD	C
CARLSBORG	A
CARLSON	C
CARLTON	B
CARMI	B
CARNASAW	C
CARNEGIE	C
CARNERO	C
CARNEY	D
CAROLINE	C
CARR	B
CARRISALITOS	D
CARRIZO	A
CARSITAS	A
CARSLEY	C
CARSO	D
CARSON	D
CARSTAIRS	B
CARSTUMP	C
CART	B
CARTAGENA	D
CARTEOAY	C
CARUSO	C
CARUTHERSVILLE	B
CARVER	A
CARWILE	D
CARYVILLE	B
CASA GRANDE	C
CASCADE	C
CASCAJO	B
CASCILLA	B
CASCO	B
CASE	B
CASEBIER	D
CASEY	C
CASHEL	C
CASHION	D
CASHMERE	B
CASHMONT	B
CASINO	A
CASITO	D
CASPAR	B
CASPIANA	B
CASS	A
CASSADAGA	
CASSIA	C
CASSIRO	C
CASSOLARY	B
CASSVILLE	
CASTAIC	C
CASTALIA	C
CASTANA	B
CASTELL	C
CASTILE	B
CASTINO	C
CASTLE	D
CASTLEVALE	D
CASTNER	C
CASTO	C
CASTRO	C
CASTROVILLE	B
CASUSE	D
CASWELL	D
CATALINA	B
CATALPA	C
CATANO	A
CATARINA	D
CATAULA	C
CATAWBA	B
CATH	D
CATHCARI	C
CATHEDRAL	D
CATHERINE	B/D
CATHRO	D
CATLET	C/D
CATLIN	B
CATNIP	D
CATOCTIN	C
CATOOSA	B
CATSKILL	A
CATTARAUGUS	C
CAUDLE	B
CAVAL	B
CAVE	D
CAVELT	D
CAVE ROCK	A
CAVO	D
CAVODE	C
CAVOUR	D
CAWKER	B
CAYAGUA	C
CAYLOR	B
CAYUGA	C
CAZADERO	C
CAZADOR	B
CAZENOVIA	B
CEBOLIA	C
CEBONE	C
CECIL	B
CEDA	B
CEDARAN	D
CEDAR BUTTE	C
CEDAREDGE	B
CEDAR MOUNTAIN	D
CEDARVILLE	B
CEDONIA	B
CEDRON	C/D
CELAYA	B
CELETON	D
CELINA	C
CELIO	A/D
CELLAR	D
CENCOVE	B
CENTER	C
CENTER CREEK	B
CENTERFIELD	B
CENTERVILLE	D
CENTRALIA	B
CENTRAL POINT	B
CERESCO	A
CERRILLOS	B
CERRO	C
CHACRA	C
CHAFFEE	C
CHAGRIN	B
CHAIX	B
CHALFONT	C
CHALMERS	C
CHAMA	B
CHAMBER	C
CHAMBERINO	C
CHAMISE	B
CHAMOKANE	B
CHAMPION	B
CHANCE	B/D
CHANDLER	B
CHANEY	C
CHANNAHON	B
CHANNING	B
CHANTA	B
CHANTIER	D
CHAPIN	C
CHAPMAN	
CHAPPELL	B
CHARD	B
CHARGO	D
CHARITON	D
CHARITY	D
CHARLEBOIS	C
CHARLESTON	C
CHARLEVOIX	B
CHARLOS	A
CHARLOTTE	A/D
CHARLTON	B
CHASE	C
CHASEBURG	B
CHASEVILLE	A
CHASKA	C
CHASTAIN	D
CHATBURN	B
CHATFIELD	C
CHATHAM	B
CHATSWORTH	D
CHAUNCEY	C
CHAVIES	B
CHAWANAKEE	C
CHEADLE	C
CHECKETT	D
CHEDEHAP	B
CHEEKTOWAGA	D
CHEESEMAN	C
CHEHALEM	C
CHEHALIS	B
CHEHULPUM	D
CHELAN	B
CHELSEA	A
CHEMAWA	B
CHEMUNG	
CHEN	D
CHENA	A
CHENANGO	A
CHENEY	B
CHENNEBY	C
CHENOWETH	B
CHEQUEST	C
CHEREETE	A
CHERIONI	D
CHEROKEE	D
CHERRY	C
CHERRYHILL	B
CHERRY SPRINGS	C
CHESAW	A
CHESHIRE	B
CHESHNINA	C
CHESNIMNUS	B
CHESTER	B
CHESTERTON	C
CHETCO	D
CHETEK	B
CHEVELON	C
CHEWACLA	C
CHEWELAH	B
CHEYENNE	B
CHIARA	D
CHICKASHA	B
CHICOPEE	B
CHICOTE	D
CHIGLEY	C
CHILCOTT	D
CHILGREN	C
CHILHOWIE	C
CHILI	B
CHILKAT	C
CHILLICOTHE	C
CHILLISQUAQUE	
CHILLUM	B
CHILMARK	B
CHILO	B/D
CHILOQUIN	B
CHILOS	B
CHILSON	D
CHILTON	B
CHIMAYO	D
CHIMNEY	B
CHINA CREEK	B
CHINCHALLO	B/D
CHINIAK	A
CHINO	B/C
CHINOOK	B
CHIPETA	D
CHIPLEY	C
CHIPMAN	D
CHIPPENY	D
CHIPPEWA	B/D
CHIQUITO	C/D
CHIRICAHUA	D
CHISPA	B
CHITINA	B

CHITTENDEN	C
CHITWOOD	C
CHIVATO	D
CHIWAWA	B
CHO	C
CHOBEE	D
CHOCK	B/D
CHOCOLODDO	B
CHOPAKA	C
CHOPTANK	A
CHOPTIE	D
CHORALMONT	B
CHOSKA	B
CHOTEAU	C
CHRISTIAN	C
CHRISTIANA	B
CHRISTIANBURG	D
CHRISTY	B
CHROME	C
CHUALAR	B
CHUBBS	C
CHUCKAWALLA	B
CHUGTER	B
CHULITNA	B
CHUMMY	C/D
CHUMSTICK	C
CHUPADERA	C
CHURCH	D
CHURCHILL	D
CHURCHVILLE	D
CHURN	B
CHURNDASHER	B
CHUTE	A
CIALES	D
CIBEQUE	B
CIBO	D
CIBOLA	B
CICERO	D
CIDRAL	C
CIENEBA	C
CIMA	C
CIMARRON	C
CINCINNATI	C
CINCO	A
CINDERCONE	B
CINEBAR	B
CINTRONA	D
CIPRIANO	D
CIRCLE	C
CIRCLEVILLE	C
CISNE	D
CISPUS	A
CITICO	B
CLACKAMAS	C
CLAIBORNE	B
CLAIRE	A
CLAIREMONT	B
CLALLAM	C
CLAM GULCH	D
CLAMO	C
CLANTON	C
CLAPPER	B
CLAREMORE	D
CLARENCE	D
CLARESON	C
CLAREVILLE	C
CLARINDA	D
CLARION	B
CLARITA	D
CLARK	B
CLARK FORK	A
CLARKSBURG	C
CLARKSDALE	C
CLARKSON	B
CLARKSVILLE	B
CLARNO	B
CLARY	B
CLATO	B
CLATSOP	D
CLAVERACK	C
CLAWSON	C
CLAYBURN	B
CLAYSPRINGS	D
CLAYTON	B
CLEARFIELD	C
CLEAR LAKE	D
CLEEK	C
CLE ELUM	B
CLEGG	B
CLEMAN	B
CLEMS	B
CLEMVILLE	B
CLEORA	B
CLERF	C
CLERMONT	D
CLEVERLY	B
CLICK	A
CLIFFDOWN	B
CLIFFHOUSE	C
CLIFFORD	B
CLIFFWOOD	C
CLIFTERSON	B
CLIFTON	C
CLIFTY	B
CLIMARA	D
CLIMAX	D
CLIME	C
CLINTON	B
CLIPPER	B/C
CLODINE	D
CLONTARF	B
CLOQUALLUM	C
CLOQUATO	B
CLOQUET	B
CLOUD	D
CLOUDCROFT	D
CLOUD PEAK	C
CLOUD RIM	B
CLOUGH	D
CLOVERDALE	D
CLOVER SPRINGS	B
CLOVIS	B
CLUFF	C
CLUNIE	D
CLURDE	C
CLURO	C
CLYDE	D
CLYMER	B
COACHELLA	B
COAD	B
COAL CREEK	D
COALMONT	C
COAMO	C
COARSEGOLD	B/C
COATICOOK	C
COATSBURG	D
COBB	B
COBEN	D
COBEY	B
COBURG	C
COCHETOPA	C
COCOA	A
COCOLALLA	C
CODORUS	C
CODY	A
COE	A
COEBURN	C
COEROCK	D
COFF	D
COFFEEK	B
COGGON	B
COGSWELL	C
COHASSET	B
COHOCTAH	D
COHOE	B
COIT	C
COLLINSTON	C
COLLINSVILLE	C
COLMA	B
COLMOR	B
COLD	B
COLOCKUM	B
COLOMA	A
COLOMBO	B
COLONA	C
COLONIE	A
COLORADO	B
COLOROCK	D
COLOSO	D
COLOSSE	A
COLP	D
COLRAIN	B
COLTON	A
COLTS NECK	B
COLUMBIA	B
COLUMBINE	A
COLUSA	C
COLVILLE	B/C
COLVIN	C
COLWOOD	B/D
COLY	B
COLYER	C/D
COMER	B
COMERID	B
COMETA	D
COMFREY	C
COMITAS	A
COMLY	C
COMMERCE	C
COMO	A
COMODORE	B
COMORO	B
COMPTCHE	B
COMPTON	C
COMSTOCK	C
COMUS	B
CONALB	B
CONANT	C
CONASAUGA	C
CONATA	D
CONBOY	D
CONCHAS	C
CONCHO	C
CONCONULLY	B
CONCORD	D
CONCREEK	B
CONDA	C
CONDIT	D
CONDON	C
CONE	A
CONEJO	C
CONESTOGA	B
CONESUS	B
CONGAREE	B
CONGER	B
CONI	D
CONKLIN	B
CONLEN	B
COKEDALE	B/C
COKEL	B
COKER	D
COKESBURY	D
COKEVILLE	B
COLBATH	C/D
COLBERT	D
COLBURN	B
COLBY	B
COLCHESTER	B
COLDCREEK	B
COLDEN	D
COLD SPRINGS	C
COLE	B/C
COLEBROOK	B
COLEMAN	C
COLEMANTOWN	D
COLETO	A
COLFAX	C
COLIBRO	B
COLINAS	B
COLLAMER	C
COLLARD	B
COLLBRAN	C
COLLEEN	C
COLLEGIATE	C
COLLETT	C
COLLIER	A
COLLINGTON	B
COLLINS	C
CONLEY	C
CONNEAUT	C
CONNECTICUT	
CONNERTON	B
CONOTTON	B
CONOVER	B
CONOWINGO	C
CONRAD	B
CONROE	B
CONSER	C/D
CONSTABLE	A
CONSTANCIA	D
CONSUMO	B
CONTEE	D
CONTINE	C
CONTINENTAL	C
CONTRA COSTA	C
CONVENT	C
COOK	D
COOKPORT	C
COOLBRITH	B
COOLIDGE	B
COOLVILLE	C
COOMBS	B
COONEY	B
COOPER	C
COOTER	C
COPAKE	B
COPALIS	B
COPELAND	B/D
COPITA	B
COPLAY	
COPPER RIVER	D
COPPERTON	B
COPPOCK	B
COPSEY	D
COQUILLE	C/D
CORA	D
CORAL	C
CORBETT	B
CORBIN	B
CORCEGA	C
CORD	C
CORDES	B
CORDOVA	C
CORINTH	C
CORKINDALE	B
CORLENA	A
CORLETT	B
CORLEY	C
CORMANT	C
CORNHILL	B
CORNING	D
CORNISH	B
CORNUTT	C
CORNVILLE	B
COROZAL	C
CORPENING	D
CORRALITOS	A
CORRECO	C
CORRERA	D
CORSON	C
CORTADA	B
CORTEZ	D
CORTINA	A
CORUNNA	D
CORVALLIS	B
CORWIN	B
CORY	C
CORYDON	C
COSAD	C
COSH	C
COSHOCTON	C
COSKI	B
COSSAYUNA	C
COSTILLA	A
COTACO	C
COTATI	C
COTITO	C
COTO	C
COTOPAXI	A
COTT	B
COTTER	B
COTTERAL	B
COTTIER	B
COTTONWOOD	C
COTTRELL	C
COUCH	C
COUGAR	D
COULSTONE	B
COUNTS	C
COUPEVILLE	C

COURT	B
COURTHOUSE	D
COURTLAND	B
COURTNEY	D
COURTROCK	B
COUSE	C
COUSHATTA	B
COVE	D
COVEILO	B
COVELAND	C
COVELLO	B/C
COVENTRY	B
COVEYTOWN	C
COVINGTON	D
COWAN	A
COWARTS	C
COWDEN	D
COWDREY	C
COWEEMAN	D
COWERS	B
COWETA	C
COWICHE	B
COWOOD	C
COX	D
COXVILLE	D
COY	D
COYATA	C
COZAD	B
CRABTON	B
CRADDOCK	B
CRADLEBAUGH	D
CRAFTON	C
CRAGO	B
CRAGOLA	D
CRAIG	C
CRAIGMONT	C
CRAIGSVILLE	A
CRAMER	D
CRANE	B
CRANSTON	B
CRARY	C
CRATER LAKE	B
CRAVEN	C
CRAWFORD	D
CREAL	D
CREDDIN	C
CREDO	C
CREEDMAN	DS
CREEDMOOR	C
CREIGHTON	B
CRELDON	B
CRESBARD	C
CRESCENT	B
CRESCO	C
CRESPIN	C
CREST	C
CRESTLINE	B
CRESTMORE	
CRESTON	A
CRESWELL	C
CRETE	D
CREVA	D
CREVASSE	A
CREWS	D
CRIDER	B
CRIM	B
CRISFIELD	B
CRITCHELL	B
CRIVITZ	A
CROCKER	A
CROCKETT	D
CROESUS	C
CROFTON	B
CROGHAN	B
CROOKED	C
CROOKED CREEK	D
CROOKSTON	B
CROOM	B
CROPLEY	D
CROSBY	C
CROSS	D
CROSSVILLE	B
CROSWELL	A
CROT	D
CROTON	D
CROUCH	B
CROW	C
CROW CREEK	B
CROWFOOT	B
CROWHEART	D
CROW HEART	D
CROW HILL	C
CROWLEY	D
CROWN	B
CROWSHAW	B
CROZIER	C
CRUCES	D
CRUCKTON	B
CRUICKSHANK	C
CRUME	B
CRUMP	D
CRUTCH	B
CRUTCHER	D
CRUZE	C
CRYSTAL LAKE	B
CRYSTAL SPRINGS	D
CRYSTOLA	B
CUBA	B
CUBERANT	B
CUCHILLAS	D
CUDAHY	D
CUERO	B
CUEVA	D
CUEVITAS	D
CULBERTSON	B
CULLEN	C
CULLEOKA	B
CULLO	C
CULPEPER	C
CULVERS	C
CUMBERLAND	B
CUMLEY	C
CUMMINGS	B/D
CUNDIYO	B
CUNICO	C
CUPPER	B
CURANT	B
CURDLI	C
CURECANTI	B
CURHOLLOW	D
CURLEW	C
CURRAN	C
CURTIS CREEK	D
CURTIS SIDING	A
CUSHING	B
CUSHMAN	C
CUSTER	C
CUTTER	D
CUTZ	D
CUYAMA	B
CUYON	A
CYAN	D
CYLINDER	B
CYNTHIANA	C/D
CYPREMORT	C
CYRIL	B
DABOB	B
DACONO	C
DACOSTA	D
DADE	A
DAFTER	B
DAGFLAT	C
DAGGETT	A
DAGLUM	D
DAGOR	B
DAGUAO	C
DAGUEY	C
DAHLQUIST	B
DAIGLE	C
DAILEY	A
DAKOTA	B
DALBO	B
DALBY	D
DALCAN	C
DALE	B
DALHART	B
DALIAN	B
DALLAM	B
DALTON	C
DALUPE	B
DAMASCUS	D
DAMON	D
DANA	B
DANBURY	C
DANBY	
DANDREA	C
DANDRIDGE	D
DANGBERG	D
DANIC	C
DANIELS	B
DANKO	D
DANLEY	C
DANNEMORA	D
DANSKIN	B
DANT	D
DANVERS	C
DANVILLE	C
DANZ	B
DARCO	A
DARGOL	D
DARIEN	C
DARLING	B
DARNELL	C
DARNEN	B
DARR	A
DARRET	C
DARROCH	C
DARROUZETT	C
DART	A
DARVADA	D
DARWIN	D
DASSEL	D
DAST	C
DATEMAN	C
DATINO	C
DATWYLER	C
DAULTON	D
DAUPHIN	
DAVEY	A
DAVIDSON	B
DAVIS	B
DAVISON	B
DAVTONE	B
DAWES	C
DAWHOO	B/D
DAWSON	D
DAXTY	C
DAY	D
DAYBELL	A
DAYTON	D
DAYVILLE	B/C
DAZE	D
DEACON	B
DEADFALL	B
DEAMA	C
DEAN	C
DEAN LAKE	C
DEARDURFF	B
DEARY	C
DEARYTON	B
DEATMAN	C
DEAVER	C
DEBENGER	C
DEBORAH	D
DECAN	D
DECATHON	D
DECATUR	B
DECCA	B
DECKER	C
DECKERVILLE	C
DECLO	B
DECORRA	B
DECROSS	B
DEE	C
DEEPWATER	C
DEER CREEK	C
DEERFIELD	B
DEERFORD	D
DEERING	B
DEERLODGE	D
DEER PARK	A
DEERTON	B
DEERTRAIL	C
DEFIANCE	D
DEFORD	D
DEGARMO	B/C
DEGNER	C
DE GREY	D
DEJARNET	B
DEKALB	C
DEKOVEN	D
DELA	B
DELAKE	B
DELANCO	C
DELANEY	A
DELANO	B/C
DELECO	D
DELENA	D
DELFINA	B
DELHI	A
DELICIAS	B
DELKS	B/D
DELL	C
DELLEKER	B
DELLO	A/C
DELLROSE	B
DELM	D
DELMAR	D
DELMITA	C
DELMONT	B
DELNORTE	C
DELPHI	B
DELPHILL	C
DELPIEDRA	C
DELPINE	D
DELRAY	A/
DEL REY	C
DEL RIO	B
DELSON	C
DELTA	C
DELTON	B
DELWIN	A
DELYNDIA	A
DEMAST	B
DE MASTERS	B
DE MAYA	C
DEMERS	D
DEMKY	D
DEMONA	C
DEMOPOLIS	C
DEMPSEY	B
DEMPSTER	B
DENAY	B
DENHAWKEN	D
DENISON	C
DENMARK	D
DENNIS	C
DENNY	D
DENROCK	D
DENTON	D
DENVER	C
DEODAR	D
DEPEW	C
DEPOE	D
DEPORT	D
DERA	B
DERINDA	C
DERR	C
DERRICK	B
DESAN	A
DESART	C
DESCALABRADO	D
DESCHUTES	C
DESERET	C
DESERTER	B
DESHA	D
DESHLER	C
DESOLATION	C
DESPAIN	B
DETER	C
DETLOR	C
DETOUR	C
DETRA	B
DETROIT	C
DEV	B
DEVILS DIVE	D
DEVOE	D
DEVOIGNES	C/
DEVOL	B

DEVON	B
DEVORE	B
DEVOY	D
DEWARD	
DEWEY	B
DEWVILLE	B
DEXTER	B
DIA	C
DIABLO	D
DIAMOND	D
DIAMOND SPRINGS	C
DIAMONDVILLE	C
DIANEV	C
DIANOLA	D
DIAZ	C
DIBBLE	C
DICK	A
DICKEY	A
DICKINSON	C
DICKSON	C
DIGBY	C
DIGGER	C
DIGHTON	B
DILL	B
DILLARD	C
DILLDOWN	
DILLINGER	B
DILLON	D
DILLWYN	A
DILMAN	C
DILTS	D
DILWORTH	D
DIMAL	D
DIMYAW	C
DINGLE	B
DINGLISHNA	D
DINKELMAN	B
DINKEY	A
DINNEN	B
DINSDALE	B
DINUBA	B/C
DINZER	B
DIOXICE	B
DIPMAN	D
DIQUE	B
DISABEL	D
DISAUTEL	B
DISCO	B
DISHNER	D
DISTERHEFF	C
DITCHCAMP	C
DITHOD	C
DIVERS	B
DIVIDE	B
DIX	A
DIXIE	C
DIXMONT	C
DIXMORE	B
DIXONVILLE	C
DIXVILLE	A
DOAK	B
DOBBS	C
DOBEL	D
DOBROW	D
DOBY	D
DOCAS	B
DOCKERY	C
DOCT	B
DODGE	B
DODGEVILLE	B
DODSON	C
DOGER	A
DOGUE	C
DOLAND	B
DOLE	C
DOLLAR	B
DOLLARD	C
DOLORES	B
DOLPH	C
DUMEZ	C
DOMINGO	C
DOMINGUEZ	C
DOMINIC	A
DOMINO	C
DOMINSON	A
DONA ANA	B
DONAHUE	C
DONALD	B
DONAVAN	B
DONEGAL	
DONERAIL	C
DONEY	C
DONICA	A
DONLONTON	C
DONNA	D
DONNAN	C
DONNAROO	B
DONNYBROOK	D
DONOVAN	B
DOOLEY	A
DOONE	B
DOOR	B
DORA	D
DORAN	C
DORCHESTER	B
DOROSHIN	D
DOROTHEA	C
DOROVAN	D
DORS	B
DORSET	B
DOS CABEZAS	C
DOSS	C
DUSSMAN	B
DOTEN	D
DOTHAN	B
DOTTA	B
DOTY	B
DOUBLETOP	B
DOUDS	B
DOUGHERTY	A
DOUGHTY	A
DOUGLAS	B
DOURO	B
DOVER	B
DOVRAY	D
DOW	B
DOWAGIAC	B
DOWDEN	C
DOWELLTON	D
DOWNER	B
DOWNEY	B
DOWNS	B
DOXIE	C
DOYCE	C
DOYLE	A
DOYLESTOWN	D
DOYN	C
DRA	C
DRACUT	C
DRAGE	B
DRAGOON	B
DRAGSTON	C
DRAHAT	D
DRAIN	D
DRAKE	B
DRANYON	B
DRAPER	C
DRESDEN	B
DRESSLER	C
DREWS	B
DREXEL	B
DRIFTON	C
DRIGGS	B
DRUM	C
DRUMMER	B
DRUMMOND	D
DRURY	B
DRYAD	C
DRYBURG	B
DRY CREEK	C
DRYDEN	B
DRY LAKE	C
DUANE	B
DUART	C
DUDAXELLA	C
DUBAY	D
DUBBS	B
DUBOIS	C
DUBUQUE	B
DUCEY	B
DUCHESNE	B
DUCKETT	C
DUCOR	D
DUDA	A
DUDLEY	D
DUEL	B
DUELM	C
DUFFAU	B
DUFFER	D
DUFFIELD	B
DUFFSON	B
DUFFY	B
DUFUR	B
DUGGINS	D
DUGOUT	D
DUGWAY	D
DUKES	A
DULAC	C
DUMAS	B
DUMECO	C
DUMONT	B
DUNBAR	D
DUNBARTON	C
DUNBRIDGE	B
DUNCAN	D
DUNCANNON	B
DUNCOM	D
DUNDAS	C
DUNDAY	A
DUNDEE	C
DUNELLEN	B
DUNE SAND	A
DUNGENESS	B
DUN GLEN	C
DUNKINSVILLE	B
DUNKIRK	B
DUNLAP	B
DUNMORE	B
DUNNING	D
DUNPHY	D
DUNUL	A
DUNVILLE	B
DU PAGE	B
DUPEE	C
DUPLIN	C
DUPO	C
DUPONT	D
DUPREE	D
DURALDE	C
DURAND	B
DURANT	D
DURELLE	B
DURHAM	B
DURKEE	C
DUROC	B
DURRSTEIN	D
DUSTON	B
DUTCHESS	B
DUTSON	D
DUTTON	D
DUVAL	B
DZEL	B
DWIGHT	D
DWYER	A
DYE	D
DYER	
DYKE	B
DYRENG	D
EACHUSTON	D
EAD	C
EAGAR	B
EAGLECONE	B
EAKIN	B
EDDS	B
EDDY	C
EDEN	C
EDENTON	C
EDENVALE	D
EDGAR	B
EDGECUMBE	B
EDGELEY	C
EDGEMONT	B
EDGEWATER	C
EDGEWICK	B
EDGEWOOD	A
EDGINGTON	C
EDINA	D
EDINBURG	C
EDISON	B
EDISTO	C
EDITH	A
EDLOE	B
EDMONDS	D
EDMORE	D
EDMUND	C
EDNA	D
EDNEYVILLE	B
EDOM	C
EDROY	D
EDSON	C
EDWARDS	B/D
EEL	C
EFFINGTON	D
EFMUN	A
EGAM	C
EGAN	B
EAMES	B
EARLE	D
EARLMONT	B/C
EARP	B
EASLEY	D
EAST FORK	C
EAST LAKE	A
EASTLAND	C
EASTON	C
EASTONVILLE	A
EAST PARK	D
EASTPORT	A
EATONTOWN	
EAUGALLIE	B/D
EBA	C
EBBERT	D
EBBS	B
EBENEZER	C
ECCLES	B
ECHARD	C
ECHLER	B
ECKERT	D
ECKLEY	B
ECKMAN	B
ECKRANT	D
ECTOR	D
EDALGO	C
EGBERT	B/C
EGELAND	B
EGGLESTON	B
EGNAR	C
EICKS	C
EIPORT	C
EKAH	C
EKALAKA	B
ELAN	A
ELBERT	D
ELBURN	B
ELCO	B
ELD	B
ELDER	B
ELDER HOLLOW	D
ELDERON	B
ELDON	B
ELDORADO	C
ELDRIDGE	C
ELEPHANT	D
ELEROY	B
ELFRIDA	B
ELIJAH	C
ELIOAK	C
ELK	B
ELKADER	B
ELKCREEK	C
ELK HOLLOW	B
ELKHORN	B
ELKINS	D
ELKINSVILLE	B
ELKMOUND	C
ELK MOUNTAIN	B
ELKOL	D
ELKTON	D

ELLABELLE	B/D
ELLEDGE	C
ELLERY	D
ELLETT	D
ELLIBER	[illegible]
ELLICOTT	A
ELLINGTON	B
ELLINOR	C
ELLIOTT	C
ELLIS	D
ELLISFORDE	C
ELLISON	B
ELLOAM	D
ELLSBERRY	C
ELLSWORTH	C
ELLUM	C
ELMA	B
ELMDALE	B
ELMENDORF	D
ELMIRA	A
ELMO	C
ELMONT	B
ELMORE	B
ELMWOOD	C
ELNORA	B
ELOIKA	B
ELPAN	D
EL PECO	C
EL RANCHO	B
ELRED	B/D
ELROSE	B
ELS	A
ELSAH	B
ELSINBORO	B
ELSINORE	A
ELSMERE	A
ELSO	D
EL SOLYO	C
ELSTON	B
ELTOPIA	B
ELTREE	B
ELTSAC	D
ELWHA	B
ELWOOD	C
ELY	B
ELYSIAN	B
ELZINGA	B
EMBDEN	B
EMBRY	B
EMBUDO	B
EMDENT	C
EMER	C
EMERALD	B
EMERSON	B
EMIDA	D
EMIGRANT	B
EMIGRATION	D
EMILY	B
EMLIN	B
EMMA	C
EMMERT	A
EMMET	B
EMMONS	C
EMORY	B
EMPEDRADO	C
EMPEY	B
EMPEYVILLE	C
EMPIRE	C
EMRICK	B
ENCE	B
ENCIERRO	D
ENCINA	B
ENDERS	C
ENDERSBY	B
ENDICOTT	C
ENET	B
ENFIELD	B
ENGLE	B
ENGLESIDE	B
ENGLEWOOD	C
ENGLUND	D
ENNIS	B
ENOCHVILLE	B/D
ENOLA	B
ENON	C
ENOREE	D
ENOS	B
ENOSBURG	D
ENSENADA	B
ENSIGN	D
ENSLEY	D
ENSTROM	B
ENTENTE	B
ENTERPRISE	B
ENTIAT	D
ENUMCLAW	C
EPHRAIM	C
EPHRATA	B
EPLEY	B
EPOUFETTE	D
EPPING	D
EPSIE	D
ERA	B
ERAM	C
ERBER	C
ERIC	B
ERIE	C
ERIN	B
ERNEST	C
ERNO	B
ERRAMOUSPE	C
ESCABOSA	C
ESCAL	B
ESCALANTE	B
ESCAMBIA	C
ESCONDIDO	C
ESMOND	B
ESPARTO	B
ESPIL	D
EPINAL	A
ESPLIN	D
ESPY	C
ESQUATZEL	B
ESS	B
ESSEN	C
ESSEX	C
ESSEXVILLE	D
ESTACADO	B
ESTELLINE	B
ESTER	D
ESTERBROOK	B
ESTHERVILLE	B
ESTIVE	C
ESTO	B
ESTRELLA	B
ETHAN	B
ETHETE	B
ETHRIDGE	C
ETIL	A
ETNA	
ETOE	B
ETOWAH	B
ETOWN	B
ETSEL	D
ETTA	C
ETTER	B
ETTERSBURG	B
ETTRICK	D
EUBANKS	B
EUDORA	B
EUFAULA	A
EUREKA	D
EUSTIS	A
EUTAW	D
EVANGELINE	C
EVANS	B
EVANSTON	B
EVARO	A
EVART	D
EVENDALE	C
EVERETT	B
EVERGLADES	A/D
EVERLY	B
EVERMAN	C
EVERSON	D
EVESBORO	A
EWA	B
EWAIL	A
EWALL	A
EWINGSVILLE	B
EXCELSIOR	B
EXCHEQUER	D
EXETER	C/D
EXLINE	D
EXRAY	D
EXUM	C
EYERBOW	D
EYRE	B
FABIUS	B
FACEVILLE	B
FAHEY	B
FAIN	C
FAINES	A
FAIRBANKS	B
FAIRDALE	B
FAIRFAX	B
FAIRFIELD	B
FAIRHAVEN	B
FAIRMOUNT	D
FAIRPORT	C
FAIRYDELL	C
FAJARDO	C
FALAYA	C
FALCON	D
FALFA	C
FALFURRIAS	A
FALK	B
FALKNER	C
FALL	B
FALLBROOK	B/C
FALLON	C
FALLSBURG	C
FALLSINGTON	D
FANCHER	C
FANG	B
FANNIN	B
FANNO	C
FANU	C
FARADAY	B
FARALLONE	B
FARAWAY	D
FARB	D
FARGO	D
FARISITA	C
FARLAND	B
FARMINGTON	C/D
FARNHAM	B
FARNHAMTON	B/C
FARNUF	B
FARNUM	B
FARRAGUT	C
FARRAR	B
FARRELL	B
FARRENBURG	B
FARROT	C
FARSON	B
FARWELL	C
FASKIN	B
FATIMA	B
FATTIG	C
FAUNCE	A
FAUQUIER	C
FAUSSE	D
FAWCETT	C
FAWN	B
FAXON	D
FAYAL	C
FAYETTE	B
FAYETTEVILLE	B
FAYWOOD	C
FE	D
FEDORA	B
FELAN	A
FELDA	B/D
FELIDA	B
FELKER	D
FELLOWSHIP	D
FELT	B
FELTA	C
FELTHAM	A
FELTON	B
FELTONIA	B
FENCE	B
FENDALL	C
FENWOOD	B
FERA	C
FERDELFORD	C
FERDIG	C
FERDINAND	C
FERGUS	B
FERGUSON	B
FERNANDO	B
FERN CLIFF	B
FERNDALE	B
FERNLEY	C
FERNOW	B
FERNPOINT	C
FERRELO	B
FERRIS	D
FERRON	D
FERTALINE	D
FESTINA	B
FETT	D
FETTIC	D
FIANDER	C
FIBEA	D
FIDALGO	C
FIDDLETOWN	C
FIDDYMENT	C
FIELDING	B
FIELDON	B
FIELDSON	A
FIFE	B
FIFER	D
FILLMORE	D
FINCASTLE	C
FINGAL	C
FINLEY	B
FIRESTEEL	B
FIRGRELL	B
FIRMAGE	B
FIRO	D
FIRTH	B/C
FISH CREEK	B
FISHERS	B
FISHHOOK	D
FISHKILL	
FITCH	A
FITCHVILLE	C
FITZGERALD	B
FITZHUGH	B
FIVE DOT	B
FIVEMILE	B
FIVES	B
FLAGG	B
FLAGSTAFF	C
FLAK	B
FLAMING	B
FLAMINGO	D
FLANAGAN	B
FLANDREAU	B
FLASHER	A
FLATHEAD	A
FLAT HORN	B
FLATTOP	D
FLATWILLOW	B
FLAXTON	A
FLEAK	A
FLECHADO	B
FLEER	D
FLEETWOOD	
FLEISCHMANN	D
FLEMING	C
FLETCHER	B
FLOKE	D
FLOM	C
FLOMATION	A
FLOMOT	B
FLORENCE	C
FLORESVILLE	C
FLORIDANA	B/D
FLORISSANT	C
FLOWELL	C
FLOWEREE	B
FLOYD	B
FLUETSCH	C
FLUSHING	
FLUVANNA	C
FLYGARE	B

FLYNN	D
FOARD	D
FOGELSVILLE	B
FOLA	B
FOLEY	D
FONDA	D
FONDIS	C
FONTAL	D
FONTREEN	B
FOPIANO	D
FORBES	B
FORD	D
FORDNEY	A
FORDTRAN	C
FORDVILLE	B
FORE	D
FORELAND	D
FORELLE	B
FORESMAN	B
FORESTDALE	D
FORESTER	C
FORESTON	C
FORGAY	A
FORMAN	B
FORNEY	D
FORREST	C
FORSEY	C
FORSGREN	C
FORT COLLINS	B
FORT DRUM	C
FORT LYON	B
FORT MEADE	A
FORT MOTT	A
FORT PIERCE	C
FORT ROCK	C
FORTUNA	D
FORTWINGATE	C
FORWARD	C
FOSHOME	B
FOSSUM	B
FOSTER	B/C
FOSTORIA	B
FOUNTAIN	D
FOURLOG	D
FOURMILE	B
FOUR STAR	B/C
FOUTS	B
FOX	B
FOXCREEK	B/D
FOXMOUNT	C
FOXOL	D
FOXPARK	D
FOX PARK	D
FOXTON	C
FRAILEY	B
FRAM	B
FRANCIS	A
FRANCITAS	D
FRANK	D
FRANKPORT	D
FRANKIRK	C
FRANKLIN	B
FRANKSTOWN	B
FRANKTOWN	D
FRANKVILLE	B
FRATERNIDAD	D
FRAZER	C
FRED	C
FREDENSBORG	C
FREDERICK	B
FREDON	C
FREDONIA	C
FREDRICKSON	C
FREEBURG	C
FREECE	D
FREEDOM	C
FREEHOLD	B
FREEL	B
FREEMAN	C
FREEMANVILLE	B
FREEON	B
FREER	C
FREESTONE	C
FREEZENER	C
FREMONT	C
FRENCH	C
FRENCHTOWN	D
FRENEAU	C
FRESNO	C/D
FRIANA	D
FRIANT	D
FRIDLO	C
FRIEDMAN	B
FRIENDS	D
FRIES	D
FRINDLE	B
FRIO	B
FRIZZELL	C
FROBERG	D
FROHMAN	C
FRONDORF	C
FRONHOFER	C
FRONTON	D
FROST	D
FRUITA	B
FRUITLAND	B
FRYE	C
FUEGO	C
FUERA	C
FUGAWEE	B
FULCHER	C
FULDA	C
FULLERTON	B
FULMER	B/D
FULSHEAR	C
FULTON	D
FUQUAY	B
FURNISS	B/D
FURY	B/D
FUSULINA	C
GAASTRA	C
GABALDON	B
GABBS	D
GABEL	C
GABICA	D
GACEY	D
GACHADO	D
GADDES	C
GADES	G
GADSDEN	D
GAGE	
GAGEBY	B
GAGETOWN	C
GAHEE	B
GAINES	C
GAINESVILLE	A
GALATA	D
GALE	B
GALEN	B
GALENA	C
GALEPPI	C
GALESTOWN	A
GALETON	D
GALEY	B
GALISTED	C
GALLAGHER	B
GALLATIN	A
GALLEGOS	B
GALLINA	C
GALLION	B
GALVA	B
GALVESTON	A
GALVEZ	C
GALVIN	C
GALWAY	B
GAMBLER	A
GAMBOA	B
GANNETT	D
GANSNER	D
GAPO	D
GAPPMAYER	B
GARA	B
GARBER	A
GARBUTT	B
GARCENO	C
GARDELLA	D
GARDENA	B
GARDINER	A
GARDNER'S FORK	B
GARDNERVILLE	D
GARDONE	A
GAREY	C
GARFIELD	C
GARITA	C
GARLAND	B
GARLET	A
GARLOCK	C
GARMON	C
GARMORE	B
GARNER	D
GARO	D
GARR	D
GARRARD	B
GARRETSON	B
GARRETT	B
GARRISON	B
GARTON	C
GARWIN	C
GASCONADE	D
GAS CREEK	C
GASKELL	C
GASS	D
GASSET	D
GATESBURG	A
GATESON	C
GATEVIEW	B
GATEWAY	C
GATEWOOD	D
GAULDY	B
GAVINS	C
GAVIOTA	D
GAY	D
GAYLORD	B
GAYNOR	C
GAYVILLE	B
GAZELLE	D
GAZOS	B
GEARHART	A
GEARY	B
GEE	B
GEEBURG	C
GEER	C
GEFO	A
GELKIE	B
GEM	C
GEMID	C
GEMSON	C
GENESEE	B
GENEVA	C
GENOA	D
GENOLA	B
GEORGEVILLE	B
GEORGIA	B
GERALD	D
GERBER	D
GERIG	B
GERING	B
GERLAND	C
GERMANIA	
GERMANY	B
GERRARD	D
GESTRIN	B
GETTA	C
GETTYS	C
GEYSEN	D
GHENT	C
GIBBLER	C
GIBBON	B
GIBBS	D
GIBBSTOWN	A
GIFFIN	C
GIFFORD	C
GILA	B
GILBY	B
GILCHRIST	B
GILCREST	B
GILEAD	C
GILES	B
GILFORD	B/D
GILHOULY	B
GILISPIE	C
GILLIAM	C
GILLIGAN	B
GILLS	C
GILLSBURG	C
GILMAN	B
GILMORE	C
GILPIN	C
GILROY	C
GILSON	B
GILT EDGE	D
GINAT	D
GINGER	C
GINI	B
GINSER	C
GIRARDOT	D
GIRD	A
GIVEN	C
GLADDEN	A
GLADE PARK	C
GLADSTONE	B
GLADWIN	A
GLAMIS	C
GLANN	B/C
GLASGOW	C
GLEAN	B
GLEASON	C
GLEN	B
GLENBAR	B
GLENBERG	B
GLENBROOK	D
GLENCOE	D
GLENDALE	B
GLENDIVE	B
GLENDORA	D
GLENELG	B
GLENFIELD	D
GLENFORD	C
GLENHALL	B
GLENHAM	B
GLENMORA	C
GLENNALLEN	C
GLENOMA	B
GLENROSE	B
GLENSTED	D
GLENTON	B
GLENVIEW	B
GLENVILLE	C
GLIDE	B
GLIKON	B
GLORIA	C
GLOUCESTER	A
GLOVER	C/D
GLYNDON	B
GLYNN	C
GOBLE	C
GODDARD	B
GODDE	D
GODECKE	D
GODFREY	C
GODWIN	D
GOEGLEIN	C
GOESSEL	D
GOFF	C
GOGEBIC	B
GOLBIN	C
GOLCONDA	D
GOLD CREEK	D
GOLDENDALE	B
GOLDFIELD	B
GOLDHILL	B
GOLDMAN	C
GOLDRIDGE	B
GOLDRUN	A
GOLDSBORO	C
GOLDSTON	C
GOLDSTREAM	D
GOLDVALE	C
GOLDVEIN	C
GOLIAD	C
GOLLAHER	A
GOLTRY	A
GOMEZ	B
GOMM	D
GONVICK	B
GOOCH	D
GOODALE	C
GOODING	C
GOODINGTON	C

GOODLOW	B
GOODMAN	B
GOODRICH	B
GOODSPRINGS	D
GOOSE CREEK	B
GOOSE LAKE	D
GOOSMUS	B
GORDO	B
GORDON	D
GORE	D
GORGONIO	A
GORHAM	B
GORIN	C
GORING	C
GORMAN	B
GORUS	A
GORZELL	B
GOSHEN	B
GOSHUTE	D
GOSPORT	C
GOTHAM	A
GOTHARD	D
GOTHIC	C
GOTHO	C
GOULDING	D
GOVAN	C
GOVE	B
GOWEN	B
GRABE	B
GRABLE	B
GRACEMONT	B
GRACEVILLE	B
GRADY	D
GRAFEN	B
GRAFTON	B
GRAHAM	D
GRAIL	C
GRAMM	B
GRANATH	B
GRANBY	A/D
GRANDE RONDE	D
GRANDFIELD	B
GRANDVIEW	C
GRANER	C
GRANGER	C
GRANGEVILLE	B/C
GRANILE	B
GRANO	D
GRANT	B
GRANTSBURG	C
GRANTSDALE	A
GRANVILLE	B
GRAPEVINE	C
GRASMERE	B
GRASSNA	B
GRASSY BUTTE	A
GRATZ	C
GRAVDEN	C
GRAVE	B
GRAVITY	C
GRAYCALM	A
GRAYFORD	B
GRAYLING	A
GRAYLOCK	B
GRAYPOINT	B
GRAYS	B
GREAT BEND	B
GREELEY	B
GREEN BLUFF	B
GREENBRAE	C
GREEN CANYON	B
GREENCREEK	B
GREENDALE	B
GREENFIELD	B
GREENHORN	B
GREENLEAF	B
GREENOUGH	C
GREENPORT	
GREEN RIVER	B
GREENSBORO	
GREENSON	C
GREENTON	C
GREENVILLE	B
GREENWATER	A
GREENWICH	B
GREENWOOD	D
GREER	C
GREGORY	A
GREHALEM	B
GRELL	D
GRENADA	C
GRENVILLE	B
GRESHAM	C
GREWINGK	D
GREYBACK	B
GREYBULL	C
GREYCLIFF	C
GREYS	B
GRIFFY	B
GRIGSTON	B
GRIMSTAD	B
GRISWOLD	B
GRITNEY	C
GRIVER	C
GRIZZLY	C
GROGAN	B
GROSECLOSE	C
GROSS	C
GROTON	A
GROVE	A
GROVELAND	B
GROVER	B
GROVETON	B
GROWDEN	B
GROWLER	B
GRUBBS	D
GRULLA	D
GRUMMIT	D
GRUNDY	C
GRUVER	C
GRYGLA	C
GUADALUPE	B
GUAJE	A
GUALALA	D
GUAMANI	B
GUANABANO	B
GUANAJIBO	C
GUANICA	D
GUAYABO	B
GUAYABOTA	D
GUAYAMA	D
GUBEN	B
GUCKEEN	C
GUELPH	B
GUENOC	C
GUERNSEY	C
GUERRERO	C
GUEST	D
GUIN	A
GULER	B
GULKANA	B
GUMBOOT	C
GUMBARREL	A
GUMM	B
GUMMUK	C
GUNSIGHT	B
GUNTER	A
GURABO	D
GURNEY	C
GUSTAVUS	D
GUSTIN	C
GUTHRIE	D
GUYTON	D
GWIN	D
GWINNETT	B
GYMER	C
GYPSTRUM	B
HACCKE	C
HACIENDA	D
HACK	B
HACKERS	B
HACKETTSTOWN	B
HADAR	A
HADES	C
HADLEY	B
HAGEN	B
HAGENBARTH	B
HAGENER	A
HAGER	C
HAGERMAN	C
HAGERSTOWN	C
HAGGA	B
HAGGERTY	B
HAGSTADT	C
HAGUE	A
HAIG	C
HAIKU	B
HAILMAN	B
HAINES	B/C
HAIRE	C
HALAWA	B
HALDER	C
HALE	B
HALEDON	C
HALEIWA	B
HALEY	B
HALF MOON	B
HALFORD	A
HALFWAY	D
HALGAITOH	B
HALII	B
HALIIMAILE	B
HALIS	B
HALOL	B
HALLECK	B
HALL RANCH	C
HALLVILLE	B
HALSEY	D
HAMACER	A
HAMAKUAPOKO	B
HAMAN	B
HAMAR	B
HAMBLEN	C
HAMBRIGHT	D
HAMBURG	B
HAMBY	C
HAMEL	C
HAMERLY	C
HAMILTON	A
HAMLET	B
HAMLIN	B
HAMMONTON	C
HAMPDEN	
HAMPSHIRE	C
HAMPTON	C
HAHTAH	C
HANA	A
HANALEI	C
HANAMAULU	A
HANCEVILLE	B
HANCO	D
HAND	B
HANDRAN	C
HANDSBORO	D
HANDY	D
HANEY	B
HANFORD	B
HANGAARD	C
HANGER	B
HANIPOE	B
HANKINS	C
HANKS	B
HANLY	A
HANNA	B
HANNUM	D
HANOVER	C
HANS	C
HANSEL	C
HANSKA	C
HANSON	A
HANTHO	B
HANTZ	D
HAP	B
HAPGOOD	B
HAPNEY	C
HARBORO	B
HARBOURTON	
HARCO	B
HARDEMAN	B
HARDESTY	B
HARDING	D
HARDSCRABBLE	B
HARDY	D
HARGREAVE	B
HARKERS	C
HARKEY	B
HARLAN	B
HARLEM	C
HARLESTON	C
HARLINGEN	D
HARMEHL	C
HARMONY	C
HARNEY	C
HARPER	D
HARPETH	B
HARPS	B
HARPSTER	C
HARPT	B
HARQUA	C
HARRIET	D
HARRIMAN	B
HARRIS	D
HARRISBURG	D
HARRISON	C
HARRISVILLE	C
HARSTENE	B
HARSTINE	C
HART	D
HART CAMP	C
HARTFORD	A
HARTIG	B
HARTLAND	B
HARTLETON	B
HARTLINE	B
HARTSBURG	B
HARTSELLS	B
HARTSHORN	B
HARVARD	B
HARVEL	B
HARVEY	C
HARWOOD	C
HASKI	B
HASKILL	A
HASKINS	C
HASSELL	C
HASTINGS	B
HAT	D
HATBORO	D
HATCH	C
HATCHERY	C
HATFIELD	C
HATHAWAY	B
HATTIE	C
HATTON	C
HAUBSTADT	C
HAUGAN	B
HAUSER	D
HAVANA	B
HAVEN	B
HAVERLY	B
HAVERSON	B
HAVILLAH	C
HAVINGDON	D
HAVRE	B
HAVRELON	B
HAW	B
HAWES	A
HAWI	B
HAWKEYE	A
HAWKSELL	A
HAWKSPRINGS	B
HAXTUN	A
HAYBOURNE	B
HAYBRO	C
HAYDEN	B
HAYESTON	B
HAYESVILLE	B
HAYFIELD	B
HAYFORD	C
HAYMOND	B
HAYNESS	B
HAYNIE	B
HAYPRESS	A
HAYSPUR	B/
HAYTER	B
HAYTI	D
HAYWOOD	B
HAZEL	C

HAZELAIR	D
HAZEN	B
HAZLEHURST	C
HAZLETON	B
HAZTON	D
HEADLEY	B
HEADQUARTERS	B
HEAKE	D
HEATH	C
HEATLY	A
HEBBRONVILLE	B
HEBER	B
HEBERT	C
HEBGEN	A
HEBO	D
HEBRON	C
HECHT	C
HECKI	C
HECLA	B
HECTOR	D
HEDDEN	C
HEDRICK	B
HEDVILLE	D
HEGNE	D
HEIDEN	D
HEIDTMAN	C
HEIL	D
HEIMDAL	B
HEISETON	B
HEISLER	B
HEIST	B
HEITT	C
HEITZ	D
HEIZER	D
HELDT	C
HELEMANO	C
HELENA	C
HELMER	C
HELVETIA	C
HELY	B
HEMBRE	B
HEMMI	C
HEMPFIELD	
HEMPSTEAD	C
HENCRATT	B
HENDERSON	B
HENDRICKS	B
HENEFER	C
HENKIN	B
HENLEY	C
HENLINE	C
HENNEKE	D
HENNEPIN	B
HENNINGSEN	C
HENRY	D
HENSEL	B
HENSHAW	C
HENSLEY	D
HEPLER	D
HERBERT	B
HEREFORD	B
HERKIMER	B
HERLONG	D
HERMISTON	B
HERMON	A
HERNDON	B
HERO	B
HERRERA	A
HERRICK	C
HERRON	B
HERSH	A
HERSHAL	B/D
HESCH	B
HESPER	C
HESPERIA	B
HESPERUS	B
HESSE	C
HESSEL	D
HESSELBERG	D
HESSELTINE	B
HESSLAN	C
HESSON	C
HETTINGER	D
HEXT	B
HEZEL	B
HIALEAH	D
HIAWATHA	A
HIBBARD	D
HIBBING	C
HIBERNIA	C
HICKORY	C
HICKS	B
HIDALGO	B
HIDEAWAY	D
HIDEWOOD	C
HIERRO	C
HIGHAMS	D
HIGHFIELD	B
HIGH GAP	C
HIGHLAND	B
HIGHMORE	B
HIGH PARK	B
HIHIMANU	A
HIIBNER	C
HIKO PEAK	B
HIKO SPRINGS	D
HILDRETH	D
HILEA	D
HILES	B
HILGER	B
HILGRAVE	B
HILLEMANN	C
HILLERY	D
HILLET	D
HILLFIELD	B
HILLGATE	D
HILLIARD	B
HILLON	B
HILLSBORO	B
HILLSDALE	B
HILMAR	C/D
HILO	A
HILT	B
HILTON	B
HINCKLEY	A
HINDES	C
HINESBURG	C
HINKLE	D
HINMAN	C
HINSDALE	
HINTZE	D
HIPPLE	C
HISLE	D
HITT	B
HI VISTA	C
HIWASSEE	B
HIWOOD	A
HIXTON	B
HOBACKER	B
HOBAN	C
HOBBS	B
HOBOG	D
HOBSON	C
HOCHEIM	B
HOCKING	B
HOCKINSON	C
HOCKLEY	C
HODGE	B
HODGINS	C
HODGSON	C
HOEBE	B
HOELZLE	C
HOFFMAN	C
HOFFMANVILLE	C
HOGANSBURG	B
HOGELAND	B
HOGG	C
HOGRIS	B
HOH	B
HOHMANN	C
HOKO	C
HOLBROOK	B
HOLCOMB	D
HOLDAWAY	D
HOLDEN	A
HOLDER	B
HOLDERMAN	C
HOLDERNESS	C
HOLDREGE	B
HOLLAND	B
HOLLINGER	B
HOLLIS	C/D
HOLLISTER	D
HOLLOMAN	C
HOLLOWAY	A
HOLLY	D
HOLLY SPRINGS	D
HOLLYWOOD	D
HOLMDEL	C
HOLMES	B
HOLOMUA	B
HOLOPAW	B/D
HOLROYD	B
HOLSINE	B
HOLST	B
HOLSTON	B
HOLT	B
HOLTLE	B
HOLTVILLE	C
HOLYOKE	C/D
HOMA	C
HOME CAMP	C
HOMELAKE	B
HOMER	C
HOMESTAKE	D
HOMESTEAD	B
HONAUNAU	C
HONCUT	B
HONDALE	D
HONDO	C
HONDOHO	B
HONEOYE	B
HONEY	D
HONEYGROVE	C
HONEYVILLE	C
HONN	B
HONOKAA	A
HONOLUA	B
HONOMANU	B
HONOULIULI	D
HONUAULU	A
HOOD	B
HOODLE	B
HOODSPORT	C
HOODVIEW	B
HOOKTON	C
HOOLEHUA	B
HOOPAL	D
HOOPER	D
HOOPESTON	B
HOOSIC	A
HOOT	D
HOOTEN	D
HOOVER	B
HOPEKA	D
HOPETON	C
HOPEWELL	
HOPGOOD	C
HOPKINS	B
HOPLEY	B
HOPPER	B
HOQUIAM	B
HORATIO	D
HORD	B
HOREB	B
HORNE	D
HORNELL	D
HORNING	A
HRONITOS	D
HORROCKS	B
HORSESHOE	B
HORTON	B
HORTONVILLE	B
HOSKIN	C
HOSKINNINI	D
HOSLEY	D
HOSMER	C
HOTAW	C
HOT LAKE	C
HOUDEK	B
HOUGHTON	A/D
HOUK	C
HOULKA	D
HOULTON	C/D
HOUNDBY	D
HOURGLASS	B
HOUSATONIC	D
HOUSEMOUNTAIN	D
HOUSEVILLE	C
HOUSTON	D
HOUSTON BLACK	D
HOYDE	A/C
HOVEN	D
HOVENWEEP	C
HOVERT	D
HOVEY	C
HOWARD	B
HOWELL	C
HOWLAND	C
HOVE	B
HOYLETON	C
HOYPUS	A
HOYTVILLE	D
HUBBARD	A
HUBERLY	D
HUBERT	B
HUBLERSBURG	C
HUCKLEBERRY	C
HUDSON	C
HUECO	C
HUEL	A
HUENEME	B/C
HUERHUERO	D
HUEY	D
HUFFINE	A
HUGGINS	C
HUGHES	B
HUGHESVILLE	B
HUGO	B
HUICHICA	C/D
HUIKAU	A
HULETT	B
HULLS	C
HULLT	B
HULUA	D
HUM	B
HUMACAO	B
HUMATAS	C
HUMBARGER	B
HUMBIRD	C
HUMBOLDT	D
HUMDUN	B
HUME	C
HUMESTON	C
HUMMINGTON	C
HUMPHREYS	B
HUMPTULIPS	B
HUNSAKER	B/C
HUNTERS	B
HUNTING	C
HUNTINGTON	B
HUNTSVILLE	B
HUPP	B
HURDS	B
HURLEY	D
HURON	C
HURST	D
HURWAL	B
HUSE	C
HUSSA	B/D
HUSSMAN	D
HUTCHINSON	C
HUTSON	B
HUXLEY	D
HYAM	D
HYAT	A
HYATTVILLE	C
HYDABURG	D
HYDE	D
HYDRO	C
HYMAS	D
HYRUM	B
HYSHAM	D
IAO	C
IBERIA	D
ICENE	C
IDA	B
IDABEL	B
IDAK	B

IDANA	C
IDEON	D
IDMON	B
IGNACIO	C
IGO	D
IGUALDAD	D
IHLEN	D
IJAM	D
ILDEFONSO	B
ILKA	B
ILLION	B/D
IMA	B
IMBLER	B
IMLAY	C
IMMOKALEE	B/D
IMPERIAL	D
INAVALE	A
INDART	B
INDIAHOMA	D
INDIAN	
INDIAN CREEK	D
INDIANO	C
INDIANOLA	A
INDIO	B
INGA	B
INGALLS	B
INGARD	B
INGENIO	C
INGRAM	D
INKLER	B
INKS	D
INMACHUK	D
INMAN	C
INNO	A
INNESVALE	D
INSKIP	C
INVERNESS	D
INVILLE	B
INWOOD	C
IO	B
IOLA	A
IOLEAU	C
IONA	B
IONIA	B
IOSCO	B
IPAVA	B
IRA	C
IREDELL	D
IRETEBA	C
IRIM	C
IROCK	B
IRON BLOSSOM	D
IRION MOUNTAIN	D
IRON RIVER	B
IRONTON	C
IRRIGFON	C
IRVINGTON	C
IRWIN	D
ISAAC	C
ISAAQUAH	B/C
ISAN	D
ISANTI	D
ISBELL	C
ISHAM	C
ISHI PISHI	C
ISLAND	B
ISOM	B
ISSAQUAH	B/C

ISTOKPOGA	D
ITCA	D
IUKA	C
IVA	C
IVAN	B
IVES	B
IVIE	A
IVINS	C
IZAGORA	C
IZEE	C
JABU	C
JACAGUAS	B
JACANA	D
JACINTO	B
JACK CREEK	A
JACKLIN	B
JACKNIFE	C
JACKPORT	D
JACKS	C
JACKSON	B
JACKSONVILLE	C
JACOB	D
JACOBSEN	D
JACOBY	C
JACQUES	C
JACQUITH	C
JACWIN	B
JAFFREY	A
JAGUEYES	B
JAL	B
JALMAR	A
JAMES CANYON	B/C
JAMESTOWN	C
JANE	C
JANISE	C
JANSEN	A
JARAB	D
JARBOE	C
JARITA	C
JARRE	B
JARVIS	B
JASPER	B
JAUCAS	A
JAVA	B
JAY	C
JAYEM	B
JAYSON	D
JEAN	A
JEANERETTE	D
JEAN LAKE	B
JEDD	C
JEDDO	D
JEFFERSON	B
JEKLEY	C
JELM	D
JENA	B
JENKINS	B
JENKINSON	D
JENNESS	B
JENNINGS	C
JENNY	D
JERAULD	D
JERICHO	C
JEROME	C
JERRY	C
JESBEL	D

JESSE CAMP	C
JESSUP	C
JETT	B
JIGGS	C
JIM	C
JIMENEZ	C
JIMTOWN	C
JOB	C
JOBOS	C
JOCITY	B
JOCKO	A
JODERO	B
JOEL	B
JOES	B
JOHNS	C
JOHNSBURG	D
JOHNSON	B
JOHNSTON	B/D
JOHNSWOOD	B
JOICE	D
JOLAN	C
JOLIET	C
JONESVILLE	A
JONUS	B
JOPLIN	B
JOPPA	B
JORDAN	D
JORGE	B
JORNADA	C
JORY	C
JOSE	C
JOSEPHINE	B
JOSIE	B
JOY	B
JUANA DIAZ	B
JUBILEE	C
JUDD	D
JUDITH	B
JUDKINS	C
JUDSON	B
JUDY	C
JUGET	D
JUGHANDLE	B
JULES	B
JULESBURG	A
JULIAETTA	B
JUMPE	B
JUNCAL	C
JUNCOS	D
JUNCTION	B
JUNEAU	B
JUNIATA	
JUNIPERO	B
JUNIUS	C
JUNO	B
JUNQUITOS	C
JURA	C
JUVA	B
JUVAN	D
KAALUALU	A
KACHEMAK	B
KADAKE	D
KADASHAN	B
KADE	C
KADIN	B
KADOKA	B
KAENA	D

KAHALUU	D
KAHANA	B
KAHANUI	B
KAHLER	B
KAHOLA	B
KAH SHEETS	D
KAHUA	D
KAIKLI	D
KAILUA	A
KAIMU	A
KAINALIU	A
KAIPOIOI	B
KAIWIKI	A
KALAE	B
KALALOCH	B
KALAMA	C
KALAMAZOO	B
KALAPA	B
KALAUPAPA	D
KALIFONSKY	D
KALIHI	D
KALISPELL	A
KALKASKA	A
KALMIA	B
KALOKO	D
KALOLOCH	B
KALSIN	D
KAMACK	B
KAMAKOA	A
KAMAOA	B
KAMAOLE	B
KAMAY	D
KAMIE	B
KAMRAR	B
KANABEC	B
KANAKA	B
KANAPAHA	A/D
KANDIK	B
KANE	B
KANEOHE	B
KANEPUU	B
KANIMA	C
KANLEE	B
KANOSH	C
KANZA	D
KAPAA	A
KAPAPALA	B
KAPOD	B
KAPOWSIN	C
KAPUHIKANI	D
KARAMIN	B
KARDE	B
KARHEEN	D
KARLAN	C
KARLIN	A
KARLO	D
KARLUK	D
KARNAK	D
KARNES	B
KARRO	B
KARS	A
KARSHNER	D
KARTA	C
KARTAR	B
KASCHMIT	D
KASHWITNA	B
KASILOF	A
KASKI	B

KASOTA	C
KASSLER	A
KASSON	C
KATAMA	B
KATEMCY	C
KATO	C
KATRINE	B
KATULA	B
KATY	C
KAUFMAN	D
KAUPO	A
KAVETT	D
KAWAIHAE	C
KAWAIHAPAI	B
KAWBAWGAM	C
KAWICH	A
KAWKAWLIN	C
KEAAU	D
KEAHUA	B
KEALAKEKUA	C
KEALIA	D
KEANSBURG	D
KEARNS	B
KEATING	C
KEAUKAHA	D
KEAWAKAPU	B
KEBLER	B
KECH	D
KECKO	B
KEDRON	C
KEEFERS	C
KEEGAN	
KEEI	D
KEFKEE	B
KEELDAR	B
KEENE	C
KEENO	C
KEESE	D
KEG	B
KEHENA	C
KEIGLEY	C
KEISER	B
KEITH	B
KEKAHA	B
KEKAKE	D
KELLER	C
KELLY	D
KELN	C
KELSEY	D
KELSO	C
KELTNER	B
KELVIN	C
KEMMERER	C
KEMOO	B
KEMPSVILLE	B
KEMPTON	B
KENAI	C
KENANSVILLE	A
KENDAIA	C
KENDALL	B
KENDALLVILLE	B
KENESAW	B
KENMOOR	B
KENNALLY	B
KENNAN	B
KENNEBEC	B
KENNEDY	B/C
KENNER	D

KENNEWICK	B
KENNEY	A
KENNEY LAKE	C
KENO	D
KENOMA	D
KENSAL	B
KENSPUR	A
KENT	D
KENYON	C
KEO	B
KEOLDAR	B
KEOMAH	C
KEOTA	C
KEOWNS	D
KEPLER	C
KERBY	B
KERMEL	B
KERMIT	A
KERMO	A
KERR	B
KERRICK	B
KERRTOWN	
KERSHAW	A
KERSICK	D
KERSTON	A/D
KERT	C
KERWIN	C
KESSLER	C
KESWICK	D
KETCHLY	B
KETTLE	B
KETTLEMAN	B
KETTNER	C
KEVIN	C
KEWAUNEE	C
KEWEENAW	A
KEYA	B
KEYES	D
KEYNER	D
KEYPORT	C
KEYSTONE	A
KEYTESVILLE	D
KEZAR	B
KIAWAH	C
KIBBIE	B
KICKERVILLE	B
KIDD	D
KIDMAN	B
KIEHL	A
KIETZKE	D
KIEV	B
KIKONI	B
KILARC	D
KILAUEA	B
KILBOURNE	A
KILBURN	B
KILCHIS	D
KILDOR	C
KILGORE	B/D
KILKENNY	B
KILLBUCK	C/D
KILLEY	D
KILLINGWORTH	
KILLPACK	C
KILMERQUE	C
KILN	D
KILOA	A
KILOHANA	A
KILWINNING	C
KIM	B
KIMANA	B
KIMBALL	C
KIMBERLY	B
KIMBROUGH	D
KIMMERLING	D
KIMMONS	C
KIMO	C
KINA	D
KINCO	A
KINESAVE	C
KINGFISHER	B
KINGHURST	B
KINGMAN	D
KINGS	C/D
KINGSBURY	D
KINGSLEY	B
KINGS RIVER	C
KINGSTON	B
KINGSVILLE	C
KINKEAD	C
KINKEL	B
KINKORA	D
KINMAN	C
KINNEAR	B
KINNEY	B
KINNICK	C
KINREAD	D
KINROSS	D
KINSTON	D
KINTA	D
KINTON	C
KINZEL	B
KIOMATIA	A
KIONA	B
KIPLING	D
KIPP	C
KIPPEN	A
KIPSON	C
KIRK	B/D
KIRKHAM	C
KIRKLAND	D
KIRKTON	B
KIRKVILLE	C
KIRTLEY	C
KIRVIN	C
KISRING	D
KISSICK	D
KISTLER	C/D
KITCHELL	B
KITCHEN CREEK	B
KITSAP	C
KITTANNING	
KITTITAS	D
KITTREDGE	C
KITTSON	C
KIUP	B
KIVA	B
KIWANIS	A
KIZHUYAK	B
KJAR	D
KLABER	C
KLAMATH	B/D
KLAUS	A
KLAWASI	D
KLEJ	B
KLICKER	C
KLICKITAT	C
KLINE	B
KLINESVILLE	C/D
KLINGER	B
KLONKIKE	D
KLONE	B
KLOOCHMAN	C
KLOTEN	B
KLUTINA	B
KNAPPA	B
KNEELAND	C
KNIFFIN	C
KNIGHT	C
KNIK	B
KNIPPA	D
KNOB HILL	B
KNOWLES	B
KNOX	B
KNULL	C
KNUTSEN	B
KOBAR	C
KOBEH	B
KOCH	C
KODAK	C
KODIAK	B
KOEHLER	C
KOELE	B
KOEPKE	B
KOERLING	B
KOGISH	D
KOHALA	A
KOKEE	B
KOKERNOT	C
KOKO	B
KOKOKAHI	D
KOKOMO	B/D
KOLBERG	B
KOLEKOLE	C
KOLLS	D
KOLLUTUK	D
KOLOA	C
KOLOB	C
KOLOKOLO	B
KONA	D
KONAWA	B
KONNER	D
KONOKTI	C
KOOLAU	C
KOOSKIA	C
KOOTENAI	A
KOPIAH	D
KOPP	B
KOPPES	B
KORCHEA	B
KORNMAN	B
KOSMOS	D
KOSSE	D
KOSTER	C
KOSZTA	B
KOTEDO	D
KOUTS	B
KOVICH	D
KOYEN	B
KOYUKUK	B
KRADE	B
KRANZBURG	B
KRATKA	C
KRAUSE	A
KREAMER	C
KREMLIN	B
KRENTZ	C
KRESSON	C
KRUM	D
KRUSE	B
KRUZOF	B
KUBE	B
KUBLER	C
KUBLI	C
KUCERA	B
KUCK	C
KUGRUG	D
KUHL	D
KUKAIAU	A
KULA	B
KULAKALA	B/C
KULLIT	B
KUMA	B
KUNIA	B
KUNUWETA	C
KUPREANOF	B
KUREB	A
KURO	D
KUSKOKWIM	D
KUSLINA	D
KUTCH	D
KUTZTOWN	B
KVICHAK	B
KWETHLUK	A
KYLE	D
KYLER	D
LA BARGE	B
LABETTE	C
LABISH	D
LABOU	D
LABOUNTY	C
LA BOUNTY	C
LA BRIER	C
LABSHAFT	D
LACAMAS	C/D
LA CASA	C
LACITA	B
LACKAWANNA	C
LACONA	C
LACOTA	D
LACY	D
LADD	B
LADDER	D
LADELLE	B
LADOGA	C
LADUE	B
LADYSMITH	D
LA FARGE	B
LAFE	D
LAFITE	D
LA FONDA	B
LAFONT	B
LAGLORIA	B
LAGONDA	C
LA GRANDE	C
LAGRANGE	D
LAHAINA	B
LA HOGUE	B
LAHONTAN	D
LAHRITY	A
LAIDIG	C
LAIDLAW	B
LAIL	C
LAIRDSVILLE	D
LAIREP	D
LAJARA	D
LAKE	A
LAKE CHARLES	D
LAKE CREEK	C
LAKEHELEN	B
LAKEHURST	A
LAKE JANEE	B
LAKELAND	A
LAKEMONT	D
LAKEPORT	B
LAKESHORE	D
LAKESOL	B
LAKETON	B
LAKEVIEW	C
LAKEWIN	B
LAKEWOOD	A
LAKI	B
LAKIN	A
LAKOMA	D
LALAAU	A
LA LANDE	B
LALLIE	D
LAM	B/D
LAMAR	B
LAMARTINE	B
LAMBERT	B
LAMBETH	C
LAMBORN	D
LAMINGTON	D
LAMO	B
LAMONI	D
LAMONT	A
LAMONTA	D
LAMOURE	C
LAMPHIER	B
LAMPSHIRE	D
LAMSON	D
LANARK	B
LANCASTER	B
LANCE	C
LAND	D
LANDES	B
LANDISBURG	C
LANDLOW	C
LANDOUSKY	D
LANE	C
LANEY	C
LANG	B/D
LANGFORD	C
LANGHEI	B
LANGLEY	C
LANGLOIS	D
LANGOLA	B
LANGRELL	B
LANGSTON	C
LANIER	B
LANIGER	B
LANKBUSH	B
LANKIN	C
LANKTREE	C
LANOAK	B
LANSDALE	B
LANSDOWNE	C
LANSING	B

LANTIS	B
LANTON	D
LANTONIA	B
LANTZ	D
LAP	D
LA PALMA	C
LAPEER	B
LAPINE	A
LAPLATTA	C
LAPON	D
LAPORTE	C
LA POSTA	A
LA PRAIRIE	B
LARABEE	B
LARAND	B
LARCHMOUNT	B
LARDELL	C
LAREDO	B
LARES	C
LARGENT	D
LARGO	B
LARIM	A
LARIMER	B
LARKIN	B
LARKSON	C
LA ROSE	B
LARRY	D
LARSON	D
LARUE	A
LARVIE	D
LAS	C
LAS ANIMAS	C
LASAUSES	C
LAS FLORES	D
LASHLEY	
LASIL	D
LAS LUCAS	C
LAS POSAS	C
LASSEN	D
LASTANCE	B
LAS VEGAS	D
LATAH	C
LATAHCO	C
LATANG	B
LATANIER	D
LATENE	B
LATHAM	D
LATHROP	C
LATINA	D
LATOM	D
LATONIA	B
LATTY	D
LAUDERDALE	B
LAUGENOUR	B/D
LAUGHLIN	B
LAUMAIA	B
LAUREL	C
LAURELHURST	C
LAURELWOOD	B
LAUREN	B
LAVALEE	B
LAVATE	B
LAVEEN	B
LAVELDO	D
LAVERKIN	C
LA VERKIN	C
LAVINA	C
LAWAI	B
LAWET	C
LAWLER	B
LAWRENCE	C
LAWRENCEVILLE	C
LAWSHE	C
LAWSON	B
LAWTHER	D
LAWTON	C
LAX	C
LAXAL	B
LAYCOCK	B
LAYTON	A
LAZEAR	D
LEA	C
LEADER	B
LEADPOINT	B
LEADVALE	C
LEADVILLE	B
LEAF	D
LEAHY	C
LEAL	B
LEAPS	C
LEATHAM	C
LEAVENWORTH	B
LEAVITT	B
LEAVITTVILLE	B
LEBANON	C
LEBAR	B
LE BAR	B
LEBEC	B
LEBO	C
LEBSACK	C
LECK KILL	B
LEDBEDER	B
LEDGEFORK	A
LEDGER	D
LEDRU	D
LEDY	
LEE	D
LEEDS	C
LEEFIELD	C
LEELANAU	A
LEEPER	D
LEESVILLE	B/C
LEETON	C
LEETONIA	C
LEFOR	B
LEGLER	B
LEGORE	B
LEHEW	C
LEHIGH	C
LEHMANS	D
LEHR	B
LEICESTER	C
LEILEHUA	B
LELA	D
LELAND	D
LEMETA	D
LEMING	C
LEMM	B
LEMONEX	D
LEMPSTER	C/D
LEN	C
LENA	A
LENAPAH	D
LENAWEE	B/D
LENNEP	D
LENOIR	D
LENOX	B
LENZ	B
LEO	B
LEON	A/D
LEONARD	C
LEONARDO	B
LEONARDTOWN	D
LEONIDAS	B
LEOTA	C
LEPLEY	D
LERDAL	C
LEROY	B
LESAGE	B
LESHARA	B
LESHO	C
LESLIE	D
LESTER	B
LE SUEUR	B
LETA	C
LETCHER	D
LETHA	D
LETHENT	C
LETORT	B
LETTERBOX	B
LEVAN	A
LEVASY	C
LEVERETT	C
LEVIATHAN	B
LEVIS	C
LEWIS	D
LEWISBERRY	B
LEWISBURG	C
LEWISTON	C
LEWISVILLE	C
LEX	B
LEXINGTON	B
LHAZ	B
LIBBINGS	D
LIBBY	B
LIBEG	A
LIBERAL	D
LIBERTY	C
LIBORY	A
LIBRARY	D
LIBUTTE	D
LICK	B
LICK CREEK	D
LICKDALE	D
LICKING	C
LICKSKILLET	D
LIDDELL	D
LIEBERMAN	C
LIEN	D
LIGGET	B
LIGHTNING	D
LIGNUM	C
LIGON	D
LIHEN	A
LIHUE	B
LIKES	A
LILAH	A
LILLIWAUP	A
LIMA	B
LIMANI	B
LIMBER	B
LIMERICK	C
LIMON	C
LIMONES	B
LIMPIA	C
LINCO	B
LINCOLN	A
LINCROFT	A
LINDLEY	C
LINDSEY	D
LINDSIDE	C
LINDSTROM	B
LINDY	C
LINEVILLE	C
LINGANORE	B
LINKER	B
LINKVILLE	B
LINNE	C
LINNET	D
LINNEUS	B
LINO	C
LINOYER	B
LINSLAW	D
LINT	B
LINTON	B
LINVILLE	B
LINWOOD	A/D
LIPAN	D
LIPPINCOTT	B/D
LIRIOS	B
LIRRET	D
LISADE	B
LISAM	D
LISBON	B
LISMAS	D
LISMORE	B
LITCHFIELD	A
LITHGOW	C
LITHIA	C
LITIMBER	C
LITLE	C
LITTLEBEAR	A
LITTLEFIELD	D
LITTLE HORN	C
LITTLE POLE	D
LITTLETON	B
LITTLE WOOD	B
LITZ	C
LIV	C
LIVERMORE	A
LIVIA	D
LIVINGSTON	D
LIVONA	A
LIZE	C
LIZZANT	B
LLANOS	C
LOBDELL	C
LOBELVILLE	C
LOBERG	B
LOBERT	B
LOBITOS	C
LOCANE	D
LOCEY	C
LOCHSA	B
LOCKE	B
LOCKERBY	C
LOCKHARD	B
LOCKHART	B
LOCKPORT	D
LOCKWOOD	B
LOCUST	C
LODAR	D
LODEMA	A
LODI	C
LODO	D
LOFFTUS	C
LOFTON	D
LOGAN	D
LOGDELL	D
LOGGERT	A
LOGHOUSE	B
LOGY	B
LOHLER	C
LOHMILLER	C
LOHNES	A
LOIRE	B
LOLAK	D
LOLALITA	B
LOLEKAA	B
LOLETA	C/D
LOLO	A
LOLON	A
LOMA	C
LOMALTA	D
LOMAX	B
LOMIRA	B
LOMITAS	D
LONDO	C
LONE	C
LONE PINE	C
LONE RIDGE	B
LONE ROCK	A
LONETREE	A
LONGFORD	C
LONGLOIS	B
LONGMARE	D
LONGMONT	C
LONGRIE	C
LONGVAL	B
LONG VALLEY	B
LONGVIEW	C
LONOKE	B
LONTI	C
LOOKOUT	C
LOON	B
LOPER	B
LOPEZ	D
LORADALE	C
LORAIN	C/D
LORDSTOWN	C
LOREAUVILLE	C
LORELLA	D
LORENZO	A
LORETTO	B
LORING	C
LOS ALAMOS	B
LOS BANOS	C
LOSEE	B
LOS GATOS	B/C
LOS GUINEOS	C
LOSHMAN	D
LOS OSOS	C
LOS ROBLES	B
LOS TANOS	B
LOST CREEK	B

LOST HILLS	C
LOS TRANCOS	D
LOSTWELLS	B
LOTHAIR	C
LOTUS	B
LOUDON	C
LOUDONVILLE	C
LOUIE	C
LOUISA	B
LOUISBURG	B
LOUP	D
LOURDES	C
LOUVIERS	D
LOVEJOY	C
LOVELAND	C
LOVELL	C
LOVELOCK	C/D
LOWELL	C
LOWRY	B
LOWVILLE	B
LOYAL	B
LOYALTON	D
LOYSVILLE	D
LOZANO	B
LOZIER	D
LUALUALEI	D
LUBBOCK	C
LUBRECHT	C
LUCAS	C
LUCE	C
LUCEDALE	B
LUCERNE	B
LUCIEN	C
LUCILE	D
LUCILETON	B
LUCKENBACH	C
LUCKY	B
LUCKY STAR	B
LUCY	A
LUDDEN	D
LUDLOW	C
LUEDERS	C
LUFKIN	D
LUHON	B
LUJANE	C
LUKIN	C
LULA	B
LULING	D
LUMBEE	D
LUMMI	B/C
LUN	C
LUNA	C
LUNCH	C
LUNDINO	C
LUNDY	D
LUNT	C
LUPPINO	C
LUPTON	D
LURA	D
LURAY	C/
LUTE	D
LUTH	C
LUTHER	B
LUTIE	B
LUTON	D
LUVERNE	C
LUXOR	D
LUZENA	D
LYCAN	B
LYCOMING	C
LYDA	D
LYDICK	B
LYFORD	C
LYLES	B
LYMAN	C/D
LYMANSON	C
LYNCH	D
LYNCHBURG	B/D
LYNDEN	A
LYNNDYL	A
LYNN HAVEN	B/D
LYNNVILLE	C
LYNX	B
LYONMAN	C
LYONS	D
LYONSVILLE	B
LYSINE	D
LYSTAIR	B
LYTELL	B
MABANK	D
MABEN	C
MABI	D
MABRAY	D
MACAR	B
MACEDONIA	C
MACFARLANE	B
MACHETE	C
MACHIAS	B
MACHUELO	D
MACK	C
MACKEN	D
MACKINAC	B
MACKSBURG	B
MACOMB	B
MACOMBER	B
MACON	B
MACY	B
MADALIN	D
MADAWASKA	B
MADDOCK	A
MADDOX	
MADELIA	C
MADELINE	D
MADERA	D
MADISON	B
MADONNA	C
MADRAS	C
MADRID	B
MADRONE	C
MADUREZ	B
MAFURT	B
MAGALLON	B
MAGENS	B
MAGGIE	D
MAGINNIS	C
MAGNA	D
MAGNOLIA	B
MAGNUS	C
MAGOTSU	D
MAGUAYO	D
MAHAFFEY	C/D
MAHALA	C
MAHALASVILLE	B/D
MAHANA	B
MAHASKA	B
MAHER	C
MAHONING	D
MAHUKONA	B
MAIDEN	B
MAIEE	A
MAINSTAY	D
MAJADA	B
MAKAALAE	B
MAKALAPA	D
MAKAPILI	A
MAKAWAO	B
MAKAWELI	B
MAKENA	B
MAKIKI	B
MAKLAK	A
MAKOTI	C
MAL	B
MALA	B
MALABAR	A/D
MALABON	C
MALACHY	B
MALAGA	B
MALAMA	A
MALAYA	D
MALBIS	B
MALCOLM	B
MALETTI	C
MALEZA	B
MALIBU	D
MALIN	C/D
MALJAMAR	B
MALLOT	A
MALM	C
MALO	B
MALONE	B
MALOTERRE	D
MALPAIS	C
MALPOSA	C
MALVERN	C
MAMALA	D
MAMOU	C
MANAHAA	C
MANALAPAN	
MANANA	C
MANASSA	C
MANASSAS	B
MANASTASH	C
MANATEE	B/D
MANAWA	C
MANCELONA	A
MANCHESTER	A
MANDAN	B
MANDERFIELD	B
MANDEVILLE	B
MANFRED	D
MANGUM	D
MANHATTAN	A
MANHEIM	C
MANI	C
MANILA	C
MANISTEE	B
MANITOU	C
MANLEY	B
MANLIUS	C
MANLOVE	B
MANNING	B
MANOGUE	D
MANOR	B
MANSFIELD	D
MANSIC	B
MANSKER	B
MANTACHIE	C
MANTEO	C/D
MANTER	B
MANTON	B
MANTZ	B
MANU	C
MANVEL	C
MANWOOD	D
MANZANITA	C
MANZANO	C
MANZANOLA	C
MAPES	C
MAPLE MOUNTAIN	B
MAPLETON	C/D
MARAGUEZ	B
MARATHON	B
MARBLE	A
MARBLEMOUNT	B
MARCELINAS	D
MARCETTA	A
MARCIAL	D
MARCUM	B
MARCUS	C
MARCUSE	D
MARCY	D
MARDEN	C
MARDIN	C
MARENGO	C/D
MARESUA	B
MARGERUM	B
MARGUERITE	B
MARIA	B/C
MARIANA	C
MARIAS	D
MARICAO	B
MARICOPA	B
MARIETTA	C
MARILLA	C
MARINA	A
MARION	D
MARIPOSA	C
MARISSA	C
MARKES	D
MARKEY	D
MARKHAM	C
MARKLAND	C
MARKSBORO	C
MARLA	A
MARLBORO	B
MARLEAN	B
MARLETTE	B
MARLEY	C
MARLIN	D
MARLOW	C
MARLTON	C
MARMARTH	B
MARNA	D
MARPA	B
MARPLEEN	D
MARQUETTE	A
MARR	B
MARRIOTT	B
MARSDEN	C
MARSELL	B
MARSHALL	B
MARSHAN	D
MARSHDALE	C
MARSHFIELD	C
MARSING	B
MART	C
MARTELLA	B
MARTIN	C
MARTINA	A
MARTINECK	D
MARTINEZ	D
MARTINI	B
MARTINSBURG	B
MARTINSDALE	B
MARTINSON	D
MARTINSVILLE	B
MARTINTON	C
MARTY	B
MARVAN	D
MARVELL	B
MARVIN	C
MARY	C
MARYDEL	B
MARYSLAND	D
MASADA	C
MASCAMP	D
MASCHETAH	B
MASCOTTE	D
MASHEL	C
MASHULAVILLE	B/D
MASON	B
MASONVILLE	C
MASSACK	B
MASSENA	C
MASSILLON	B
MASTERSON	B
MATAGORDA	D
MATAMOROS	C
MATANUSKA	C
MATANZAS	B
MATAPEAKE	B
MATAWAN	C
MATCHER	A
MATFIELD	C
MATHERS	B
MATHERTON	B
MWATHESON	B
MATHEWS	
MATHIS	A
MATHISTON	C
MATLOCK	D
MATMON	D
MATTAPEX	C
MATTOLE	C
MAU	D
MAUDE	B
MAUGHAN	C
MAUKEY	C
MAUMEE	A/D
MAUNABO	D
MAUPIN	C
MAUREPAS	D
MAURICE	A
MAURINE	D
MAURY	B
MAVERICK	C
MAVIE	D
MAWAE	A
MAX	B
MAXEY	C

MAXFIELD	C
MAXSON	A
MAXTON	B
MAXVILLE	A
MAXWELL	D
MAY	B
MAYBERRY	C
MAYBESO	D
MAY DAY	D
MAYER	D
MAYES	D
MAYFIELD	B
MAYFLOWER	C
MAYHEW	D
MAYLAND	C
MAYMEN	D
MAYNARD LAKE	B
MAYO	B
MAYODAN	B
MAYOWORTH	C
MAYSDORF	B
MAYSVILLE	
MAYRTOWN	C
MAYVILLE	B
MAYWOOD	B
MAZEPPA	B
MAZON	C
MAZUMA	C
MCAFEE	C
MCALLEN	B
MCALLISTER	C
MCALPIN	C
MCBEE	B
MCBETH	D
MCBRIDE	B
MCCABE	B
MCCAFFERY	A
MCCAIN	C
MCCALEB	B
MCCALLY	D
MCCAMMON	D
MCCANN	C
MCCARRAN	D
MCCARTHY	B
MCCLAVE	C
MCCLEARY	C
MCCLELLAN	B
MCCLOUD	C
MCCOIN	D
MCCOLL	D
MCCONNEL	B
MCCOOK	B
MCCORMICK	C
MCCOY	C
MCCREE	B
MCCRORY	D
MCCROSKIE	D
MCCULLOUGH	C
MCCULLY	C
MCCUNE	D
MCCUTCHEN	C
MCDOLE	B
MCDONALD	B
MCDONALDSVILLE	C
MCEWEN	B
MCFADDEN	B
MCFAUL	C
MCGAFFEY	B
MCGARR	C
MCGARY	C
MCGEHEE	C
MCGILVERY	D
MCGINTY	B
MCGIRK	C
MCGOWAN	B
MCGRATH	B
MCGREW	A
MCHENRY	B
MCILWAINE	A
MCINTOSH	B
MCINTYRE	B
MCKAMIE	D
MCKAY	D
MCKENNA	C/D
MCKENZIE	D
MCKINLEY	B
MCKINNEY	D
MCLAIN	C
MCLAURIN	B
MCLEAN	C
MCLEOD	B
MCMAHON	C
MCMEEN	C
MCMULLIN	D
MCMURDIE	C
MCMURPHY	B
MCMURRAY	D
MCNARY	D
MCPAUL	B
MCPHERSON	C
MCPHIE	B
MCQUARRIE	D
MCQUEEN	C
MCRAE	B
MCTAGGART	B
MCVICKERS	C
MEAD	D
MEADIN	A
MEADOWVILLE	B
MEADVILLE	C
MEANDER	D
MECAN	B
MECCA	B
MECKESVILLE	C
MECKLENBURG	C
MEDA	B
MEDANO	C
MEDARY	C
MEDFORD	B
MEDFRA	D
MEDICINE LODGE	B
MEDINA	B
MEDLEY	B
MEDWAY	B
MEEKS	A
MEETEETSE	D
MEGGETT	D
MEGONC	C
MEHL	C
MEHLHORN	C
MEIGS	
MEIKLE	D
MEISS	D
MELBOURNE	B
MELBY	C
MELITA	B
MELLENTHIN	D
MELLOR	D
MELLOTT	B
MELOLAND	C
MELROSE	C
MELSTONE	A
MELTON	B
MELVILLE	B
MELVIN	D
MEMALOOSE	D
MEMPHIS	B
MENAHGA	A
MENAN	C
MENARD	B
MENCH	C
MENDEBOURE	C
MENDOCINO	B
MENDON	B
MENDOTA	B
MENEFEE	D
MENFRO	B
MENO	C
MENOKEN	C
MENOMINEE	B
MENTO	C
MENTOR	B
MEQUON	C
MERCED	C/D
MERCEDES	D
MERCER	C
MERCEY	C
MEREDITH	B
MERETA	C
MERGEL	B
MERIDIAN	B
MERINO	D
MERKEL	B
MERLIN	D
MERMILL	B/D
MERNA	D
MEROS	A
MERRIFIELD	B
MERRILL	C
MERRILLAN	C
MERRIMAC	A
MERRITT	B/C
MER ROUGE	B
MERTON	B
MERTZ	B
MESA	B
MESCAL	B
MESCALERO	C
MESITA	C
MESKILL	C
MESMAN	C
MESPUN	A
MESSER	C
MET	D
METALINE	B
METAMORA	B
METEA	B
METHOW	B
METIGOSHE	A
METOLIUS	B
METRE	D
METZ	A
MEXICO	D
MHOON	D
MIAMI	B
MIAMIAN	G
MICCO	A/D
MICHELSON	B
MICHIGAMME	C
MICK	B
MIDAS	D
MIDDLE	C
MIDDLEBURY	B
MIDESSA	B
MIDLAND	D
MIDNIGHT	D
MIDVALE	C
MIDWAY	D
MIFFLIN	B
MIFFLINBURG	B
MIGUEL	D
MIKE	D
MIKESELL	C
MILACA	B
MILAN	B
MILES	B
MILFORD	C
MILHAM	C
MILHEIM	C
MILL	B
MILLARD	B
MILLBORO	D
MILLBROOK	B
MILLBORNE	B
MILLCREEK	B
MILLER	D
MILLERLUX	D
MILLERTON	D
MILLETT	B
MILLGROVE	B/D
MILL HOLLOW	B
MILLICH	D
MILLIKEN	C
MILLINGTON	B
MILLIS	C
MILLRACE	B
MILLSAP	C
MILLSDALE	B/D·
MILLSHOLM	C
MILLVILLE	B
MILLWOOD	D
MILNER	C
MILPITAS	C
MILROY	D
MILTON	C
MIMBRES	C
MIMOSA	C
MINA	C
MINAM	B
MINATARE	D
MINCHEY	B
MINCO	B
MINDALE	B
MINDEGO	B
MINDEMAN	B
MINDEN	C
MINE	B
MINEOLA	
MINER	D
MINERAL	A
MINERAL MO	C
MINERVA	B
MING	B
MINGO	B
MINIDOKA	C
MINNEISKA	C
MINNEOSA	B
MINNEQUA	B
MINNETONKA	D
MINNEWAUKAN	B
MINNIECE	D
MINOA	C
MINORA	C
MINTO	C
MINU	D
MINVALE	B
MIRA	D
MIRABAL	C
MIRACLE	B
MIRAMAR	B
MIRANDA	D
MIRES	B
MIRROR	B
MIRROR LAKE	A
MISSION	B
MITCH	B
MITCHELL	B
MITIWANGA	C
MITRE	C
MIZEL	D
MIZPAH	C
MOANO	D
MOAPA	D
MOAULA	A
MOBEETIE	B
MOCA	D
MOCHO	B
MODA	D
MODALE	C
MODEL	C
MODENA	B
MODESTO	C
MODOC	C
MOENKOPIE	D
MOEPITZ	B
MOFFAT	B
MOGOLLON	B
MOGUL	B
MOHALL	B
MOHAVE	B
MOHAWK	B
MOIRA	C
MOKELUMNE	D
MOKENA	C
MOKIAK	B
MOKULEIA	B
MOLAND	B
MOLCAL	B
MOLENA	A
MOLINOS	B
MOLLVILLE	D
MOLLY	B
MOLOKAI	B
MOLSON	B
MOLYNEUX	B
MONAD	A
MONAHAN	D
MONAHANS	B
MONARDA	D
MONCLOVA	B
MONDAMIN	C

MONDOVI	B
MONEE	D
MONICO	B
MONIDA	B
MONITEAU	D
MONMOUTH	C
MONO	D
MONOLITH	C
MONONA	B
MONONGAHELA	C
MONROE	B
MONTOYA	D
MONTPIELLIER	C
MONTROSE	B
MONTVALE	D
MONTVERDE	A/D
MONTWEL	C
MONUE	B
MOODY	B
MONROEVILLE	C/D
MONSE	B
MONSERATE	C
MONTAGUE	D
MONTALTO	C
MONTARA	D
MONTAUK	C
MONTCALM	A
MONTE	B
MONTE CRISTO	D
MONTEGRANDE	D
MONTELL	D
MONTELLO	C
MONTEOLA	D
MONTEROSA	D
MONTEVALLO	D
MONTGOMERY	D
MONTICELLO	B
MONTIETH	A
MONTMORENCI	B
MONTOSO	B
MONTOUR	D
MOOHOO	B
MOOSE RIVER	D
MORA	B
MORADO	C
MORALES	D
MORD	C
MOREAU	D
MOREHEAD	C
MOREHOUSE	C
MORELAND	D
MORELANDTON	A
MORET	D
MOREY	D
MORFITT	B
MORGANFIELD	B
MORGNEC	
MORIARTY	D
MORICAL	C
MORLEY	C
MORMON MESA	D
MOROCCO	A/C
MORONI	D
MOROP	C
MORRILL	B
MORRIS	C
MORRISON	B
MORROW	C
MORSE	D
MORTENSON	C
MORTON	B
MORVAL	B
MOSBY	C
MOSCA	A
MOSCOW	C
MOSEL	C
MOSHANNON	D
MOSHER	D
MOSHERVILLE	C
MOSIDA	B
MOSQUET	D
MOSSYROCK	B
MOTA	B
MOTLEY	B
MOTOQUA	D
MOTTSVILLE	A
MOULTON	B/D
MOUND	C
MOUNTAINBURG	D
MOUNTAINVIEW	B/D
MOUNTAINVILLE	B
MOUNT AIRY	A
MOUNT CARROLL	B
MOUNT HOME	B
MOUNT HOOD	B
MOUNT LUCAS	C
MOUNT OLIVE	D
MOUNTVIEW	B
MOVILLE	C
MOWATA	D
MOWER	C
MOYERSON	D
MOYINA	D
MUCARA	D
MUCET	C
MUDRAY	D
MUD SPRINGS	C
MUGHOUSE	C
MUIR	B
MUIRKIRK	B
MUKILTEO	D
MULDROW	D
MULKEY	C
MULLINS	D
MULLINVILLE	B
MULT	C
MULTORPOR	A
MUMFORD	B
MUNDELEIN	B
MUNDOS	B
MUNISING	B
MUNK	C
MUNSON	D
MUNUSCONG	D
MURDO	B
MURDOCK	C
MUREN	B
MURRILL	B
MURVILLE	D
MUSCATINE	B
MUSE	C
MUSELLA	B
MUSICK	B
MUSINIA	B
MUSKINGUM	C
MUSKOGEE	C
MUSQUIZ	C
MUSSEL	B
MUSSELSHELL	B
MUSSEY	D
MUSTANG	A/D
MUTNALA	B
MUTUAL	B
MYAKKA	A/D
MYATT	B/D
MYERS	D
MYERSVILLE	B
MYLREA	B
MYRICK	D
MYRTLE	B
MYSTEN	A
MYSTIC	D
MYTON	B
NAALEHU	B
NEBESNA	D
NACEVILLE	C
NACHES	B
NACIMIENTO	C
NACOGDOCHES	B
NADEAN	B
NADINA	D
NAFF	B
NAGEESI	B
NAGITSY	C
NAGLE	B
NAGOS	D
NAHATCHE	C
NAHMA	C
NAHUNTA	C
NAIWA	B
NAKAI	B
NAKNEK	D
NALDO	B
NAMBE	B
NAMON	C
NANAMKIN	A
NANCY	B
NANNY	B
NANNYTON	B
NANSENE	B
NANTUCKET	C
NANUM	C
NAPA	D
NAPAISHAK	D
NAPAVINE	B
NAPIER	B
NAPLENE	B
NAPLES	B
NAPPANEE	D
NAPTOWNE	B
NARANJITO	C
NARANJO	C
NARCISSE	B
NARD	B
NARLON	C
NARON	B
NARRAGANSETT	B
NARROWS	D
NASER	B
NASH	B
NASHUA	A
NASHVILLE	B
NASON	C
NASSAU	C/D
NASSET	B
NATALIE	C
NATCHEZ	B
NATHROP	B
NATIONAL	B
NATRONA	B
NATROY	D
NATURITA	B
NAUKATI	D
NAUMBURG	C
NAVAJO	D
NAVAN	D
NAVARRO	B
NAVESINK	
NAYLOR	
NAYPED	C
NAZ	B
N-BAR	B
NEAPOLIS	B/D
NEBEKER	C
NEBGEN	D
NEBISH	B
NEBO	
NECHE	C
NEDERLAND	B
NEEDHAM	D
NEEDLE PEAK	C
NEEDMORE	C
NEELEY	B
NEESOPAH	C
NEGITA	B
NEGLEY	B
NEHALEM	B
NEHAR	B
NEILTON	A
NEISSON	B
NEKIA	C
NELLIS	B
NELMAN	B
NELSCOTT	B
NELSON	B
NEMAH	C
NEMOTE	A
NENANA	B
NENNO	B
NEOLA	D
NEOTOMA	B
NEPALTO	A
NEPESTA	C
NEPHI	B
NEPPEL	B
NEPTUNE	A
NERESON	B
NESDA	A
NESHAMINY	B
NESIKA	B
NESKAHI	B
NESKOWIN	C
NESPELEM	B
NESS	D
NESSEL	B
NESSOPAH	B
NESTER	C
NESTUCCA	C
NETARTS	A
NETCONG	B
NETO	B
NETTLETON	C
NEUBERT	B
NEUNS	B
NEUSKE	B
NEVADOR	C
NEVILLE	B
NEVIN	C
NEVINE	B
NEVKA	C
NEVOYER	D
NEVTAH	C
NEVU	D
NEWARK	C
NEWART	B
NEWAYGO	B
NEWBERG	B
NEWBERRY	C
NEWBY	B
NEW CAMBRIA	C
NEWCASTLE	B
NEWCOMB	A
NEWDALE	B
NEWELL	B
NEWELLTON	D
NEWFANE	
NEWFORK	D
NEWKIRK	D
NEWLANDS	B
NEWLIN	B
NEWMARKET	B
NEWPORT	C
NEWRUSS	B
NEWRY	B
NEWSKAH	B
NEWSTEAD	D
NEWTON	A/D
NEWTONIA	B
NEWTOWN	C
NEWVILLE	C
NEZ PERCE	C
NIAGARA	C
NIART	B
NIBLEY	C
NICHOLSON	C
NICHOLVILLE	C
NICKEL	B
NICODEMUS	B
NICOLAUS	C
NICOLLET	B
NIELSEN	D
NIGHTHAWK	B
NIHILL	B
NIKABUNA	D
NIKEY	B
NIKISHKA	A
NIKLASON	B
NIKOLAI	D
NILAND	C
NILES	C
NIMROD	C
NINCH	C
NINEMILE	D
NINEVEH	B
NINIGRET	B
NININGER	B
NINNESCAH	B
NIOBELL	C
NIOTA	D
NIPE	B
NIPPERSINK	B
NIPPT	A
NIPSUM	C

NIRA	B
NISHNA	C
NISHON	D
NISQUALLY	A
NISSWA	B
NIU	B
NIULII	C
NIVLOC	D
NIWOT	C
NIXA	C
NIXON	B
NIXONTON	B
NIZINA	A
NOBE	D
NOBLE	B
NOBSCOTT	A
NOCKEN	C
NODAWAY	B
NOEL	D
NOHILI	D
NOKASIPPI	D
NOKAY	C
NOKOMIS	B
NOLAM	B
NOLICHUCKY	B
NOLIN	B
NOLO	B
NOME	D
NONDALTON	B
NONOPAHU	D
NOOKACHAMPS	C/D
NOOKSACK	B
NOONAN	D
NORA	B
NORAD	B
NORBERT	D
NORBOURNE	B
NORBY	B
NORD	B
NORDBY	B
NORDEN	B
NORDNESS	B
NORFOLK	B
NORGE	B
NORKA	B
NORMA	B/C
NORMANGEE	D
NORREST	C
NORRIS	C
NORRISTON	B
NORTE	B
NORTHDALE	C
NORTHFIELD	B
NORTHMORE	C
NORTHPORT	
NORTH POWDER	C
NORTHUMBERLAND	C/D
NORTON	C
NORTONVILLE	C
NORTUNE	D
NORWALK	B
NORWAY FLAT	B
NORWELL	C
NORWICH	D
NORWOOD	B
NOTI	D
NOTUS	A/C
NOUQUE	D
NOVARA	B
NOVARY	B
NOWOOD	C
NOYO	C
NOYSON	C
NUBY	C/D
NUCKOLLS	C
NUCLA	B
NUECES	C
NUGENT	A
NUGGET	C
NUMA	C
NUNDA	C
NUNICA	C
NUNN	C
NUSS	D
NUTLEY	C
NUTRAS	C
NUTRIOSO	B
NUVALDE	C
NYALA	D
NYMORE	A
NYSSA	C
NYSSATON	B
NYSTROM	C
OAHE	B
OAKDALE	B
OAKDEN	D
OAKFORD	B
OAK GLEN	B
OAK GROVE	C
OAK LAKE	B
OAKLAND	C
OAKS RIDGE	C
OAKVILLE	A
OAKWOOD	D
OANAPUKA	B
OASIS	B
OATMAN	B
OBAN	C
OBARC	B
OBEN	C
OBRAST	D
OBRAY	D
OBURN	D
OCALA	D
OCEANET	D
OCEANO	A
OCHEYEDAN	B
OCHLOCKONEE	B
OCHO	D
OCHOCO	C
OCHOPEE	B/D
OCILLA	C
OCKLEY	B
OCDEE	A/D
OCONEE	C
OCONTO	B
OCOSTA	D
OCQUEOC	B
OCTAGON	B
ODEE	D
ODELL	B
ODEM	A
ODERMOTT	C
ODESSA	D
ODIN	C
ODNE	C
O'FALLON	D
OGDEN	D
OGEECHEE	C
OGEMAW	C
OGILVIE	C
OGLALA	B
OGLE	B
OHAYSI	D
OHIA	A
OJAI	B
OJATA	D
OKANOGAN	B
OKAW	D
OKAY	B
OKEECHOBEE	A/D
OKEELANTA	A/D
OKEMAH	C
OKLARED	B
OKLAWAHA	A/D
OKMOK	B
OKO	D
OKOBOJI	C
OKOLONA	D
OKREEK	D
OKTIBBEHA	D
OLA	C
OLAA	A
OLALLA	C
OLANTA	B
OLATHE	C
OLD CAMP	D
OLDHAM	C
OLDS	D
OLDSMAR	B/D
OLDWICK	B
OLELO	B
OLENA	B
OLEQUA	B
OLETE	C
OLEX	B
OLGA	C
OLI	B
OLIAGA	B/D
OLINDA	B
OLIPHANT	B
OLIVENHAIN	D
OLIVER	B
OLIVIER	C
OLJETO	A
OLMITO	D
OLMITZ	B
OLMOS	C
OLMSTED	B/D
OLNEY	B
OLOKUI	D
OLPE	C
OLSON	D
OLTON	C
OLUSTEE	B/D
OLYIC	B
OLYMPIC	B
OMADI	B
OMAHA	B
OMAK	C
OMEGA	A
OMENA	B
OMNI	C
ONA	A/D
ONALASKA	B
ONAMIA	B
ONARGA	B
ONAWA	D
ONAWAY	B
ONDAWA	B
ONEIDA	B
O'NEILL	B
ONEONTA	B
ONITRA	C
ONITE	B
ONOTA	C
ONOVA	D
ONRAY	C
ONSLOW	B
ONTARIO	B
ONTKO	B/D
ONTONAGON	D
ONYX	B
OOKALA	A
OPAL	D
OPEQUON	C/D
OPHIR	C
OPIHIKAO	D
OPPIO	D
OQUAGA	C
ORA	C
ORAN	B
ORANGE	D
ORANGEBURG	B
ORCAS	D
ORCHARD	B
ORD	A
ORDNANCE	C
ORDWAY	D
ORELIA	D
ORELLA	D
OREM	A
ORESTIMBA	C
ORFORD	C
ORIDIA	C
ORIF	A
ORIO	C
ORION	B
ORITA	B
ORLAND	B
ORLANDO	A
ORMAN	C
ORMSBY	B/C
ORODELL	C
ORO FINO	B
ORO GRANDE	C
ORONO	D
OROVADA	C
ORPHANT	D
ORR	C
ORVILLE	C
ORSA	A
ORSINO	A
ORTELLO	A
ORTIGALITA	C
ORTING	C
ORTIZ	C
ORTLEY	B
ORWET	A
ORWOOD	B
OSAGE	D
OSAKIS	B
OSCAR	D
OSCURA	C
OSGOOD	B
OSHA	B
OSHAWA	D
O'SHEA	C
OSHKOSH	C
OSHTEMO	B
OSIER	B/D
OSKA	C
OSMUND	B
OSO	B
OSOBB	D
OSORIDGE	D
OSOTE	B
OSSIAN	C
OST	B
OSTRANDER	B
OTERO	B
OTHELLO	D
OTIS	C
OTISCO	A
OTISVILLE	A
OTLEY	B
OTSEGO	C
OTTER	B/D
OTTERBEIN	C
OTTERHOLT	B
OTTOKEE	A
OTWAY	D
ORTWELL	C
OUACHITA	C
OURAY	A
OUTLET	C
OVALL	C
OVERGAARD	C
OVERLAND	C
OVERLY	C
OVERTON	D
OVID	C
OVINA	B
OWEGO	D
OWEN CREEK	C
OWENS	D
OWHI	B
OWOSSO	B
OWYHEE	B
OXALIS	C
OXBOW	C
OXERINE	C
OXFORD	D
OZAMIS	B/D
OZAN	D
OZAUKEE	C
PAAIKI	B
PAALOA	B
PAAUHAU	A
PACHAPPA	B
PACHECO	B/C
PACK	C
PACKARD	B
PACKER	C
PACKHAM	B
PACKSADDLE	B
PACKWOOD	D
PACOLET	B

PACTOLUS	C
PADEN	C
PADRONI	B
PADUCAH	B
PADUS	B
PAESL	B
PAGET	B
PAGODA	C
PAHRANAGAT	C
PAHREAH	D
PAHROC	D
PAIA	C
PAICE	C
PAINESVILLE	C
PAINTROCK	C
PAIT	B
PAJARITO	B
PAJARO	C
PAKA	B
PAKALA	B
PAKINI	B
PALA	B
PALACIO	B
PALAPALAI	B
PALATINE	B
PALESTINE	B
PALISADE	B
PALMA	B
PALMAREJO	C
PALM BEACH	A
PALMER	D
PALMER CANYON	B
PALMICH	B
PALMS	D
PALMYRA	B
PALO	B
PALDOURO	B
PALOMAS	B
PALOMINO	D
PALOS VERDES	B
PALOUSE	B
PALSGROVE	B
PAMLICO	D
PAMOA	C
PAMSDEL	D
PAMUNKEY	C
PANA	B
PANACA	D
PANAEWA	D
PANASOFFKEE	D
PANCHERI	B
PANCHUELA	C
PANDO	B
PANDOAH	C
PANDORA	D
PANDURA	D
PANE	B
PANGUITCH	B
PANHILL	B
PANIOGUE	B
PANKY	C
PANOCHE	B
PANOLA	D
PANSEY	D
PANTEGO	D
PANTHER	D
PANTON	D
PAOLA	A
PAOLI	B
PAONIA	C
PAPAA	D
PAPAI	A
PAPAKATING	D
PAPOOSE	C
PARADISE	C
PARADOX	B
PARALOMA	C
PARAMORE	D
PARASOL	B
PARCELAS	D
PARDEE	D
PAREHAT	C
PARENT	C
PARIETTE	C
PARIS	
PARISHVILLE	C
PARKAY	B
PARKDALE	B
PARKE	B
PARKER	B
PARKFIELD	C
PARKHILL	D
PARKHURST	
PARKINSON	B
PARKVIEW	B
PARKVILLE	C
PARKWOOD	A/D
PARLEYS	B
PARLIN	C
PARLO	B
PARMA	C
PARNELL	D
PARR	B
PARRAN	D
PARRISH	C
PARSHALL	B
PARSIPPANY	D
PARSONS	D
PARTRI	C
PASAGSHAK	D
PASCO	B/C
PASO SECO	D
PASQUETTI	C/D
PASQUOTANK	B/D
PASSAR	C
PASS CANYON	D
PASSCREEK	C
PASTURA	D
PATAHS	B
PATENT	C
PATILLAS	B
PATILO	C
PATIT CREEK	B
PATNA	B
PATOUTVILLE	C
PATRICIA	B
PATRICK	B
PATROLE	C
PATTANI	D
PATTENBURG	B
PATTER	C
PATTERSON	C
PATTON	B/D
PATWAY	C
PAUL	B
PAULDING	D
PAULINA	D
PAULSELL	D
PAULSON	B
PAULVILLE	B
PAUMALU	B
PAUNSAUGUNT	D
PAUSANT	B
PAUWELA	B
PAVANT	D
PAVILLION	B
PAVOHROO	B
PAWCATUCK	D
PAWLET	B
PAWNEE	D
PAXTON	C
PAXVILLE	D
PAYETTE	B
PAYMASTER	B
PAYNE	C
PAYSON	D
PEACHAM	D
PEARL HARBOR	D
PEARMAN	
PEARSOLL	D
PEAVINE	C
PECATONICA	B
PECOS	D
PEDEE	C
PEDERNALES	C
PEDIGO	B/C
PEDLAR	D
PEDOLI	C
PEDRICK	B
PEBBLES	C
PEEL	C
PEELER	B
PEEVER	C
PEGLER	D
PEGRAM	B
PEKIN	C
PELHAM	B/D
PELIC	D
PELLA	D
PELLEJAS	B
PELONA	C
PELUK	D
PEMBERTON	A
PEMBINA	C
PEMBROKE	B
PENA	B
PENCE	A
PENDEN	B
PEND OREILLE	B
PENDROY	D
PENELAS	D
PENINSULA	C
PENISTAJA	B
PENITENTE	B
PENLAW	C
PENN	C
PENNEL	C
PENNINGTON	B
PENO	C
PENOYER	C
PENROSE	D
PENSORE	D
PENTHOUSE	D
PENTZ	D
PENWELL	A
PENWOOD	A
PEOGA	C
PEOH	C
PEONE	B/C
PEORIA	D
PEOTONE	C
PEPOON	B
PEQUEA	C
PERCHAS	D
PERCIVAL	C
PERELLA	C
PERHAM	C
PERICO	B
PERITSA	C
PERKINS	C
PERKS	A
PERLA	C
PERMA	A
PERMANENTE	C
PERRIN	B
PERRINE	D
PERROT	D
PERRY	D
PERRYPARK	B
PERRYVILLE	B
PERSANTI	C
PERSAYO	D
PERSHING	C
PERSIS	B
PERT	D
PERU	C
PESCADERO	C/D
PESET	C
PEHASTIN	B
PESO	C
PETEETNEET	D
PETERBORO	B
PETERS	D
PETOSKEY	
PETRIE	D
PETROLIA	D
PETTONS	C
PEWAMO	B/D
PEYTON	B
PFEIFFER	B
PHAGE	B
PHANTOM	C
PHARO	B
PHAROLIO	D
PHEBA	C
PHEENEY	B
PHELAN	B
PHELPS	B
PHIFERSON	B
PHILBON	B/D
PHILIPSBURG	B
PHILLIPS	C
PHILO	B
PHILOMATH	D
PHIPPS	C
PHOEBE	B
PHOENIX	D
PIASA	D
PICACHO	C
PICAYUNE	B
PICKAWAY	C
PICKENS	D
PICKETT	B
PICKFORD	D
PICKRELL	D
PICKWICK	B
PICO	B
PICOSA	C
PICTOU	B
PIE CREEK	D
PIERIAN	A
PIERPONT	C
PIERRE	D
PIERSONTE	B
PIIHONUA	A
PIKE	B
PILCHUCK	A
PILGRIM	B
PILOT	B
PILOT ROCK	C
PIMA	B
PIMER	B
PINAL	D
PINALENO	B
PINAMT	B
PINATA	C
PINAVETES	A
PINCHER	C
PINCKNEY	C
PINCONNING	D
PINCUSHION	B
PINEDA	B/D
PINEDALE	B
PINEGUEST	B
PINELLOS	A/D
PINETOP	C
PINEVILLE	B
PINEY	C
PINICON	B
PINKEL	C
PINKHAM	B
PINKSTON	B
PINNACLES	C
PINO	C
PINOLA	C
PINOLE	B
PINON	C
PINONES	D
PINTAS	D
PINTLAR	A
PINTO	C
PINTURA	A
PINTWATER	D
PIOCHE	D
PIOPOLIS	D
PIPER	B/C
PIROUETTE	D
PIRUM	B
PISGAH	C
PISHKUN	B
PISTAKEE	B
PIT	D
PITTMAN	D
PITTSFIELD	B
PITTSTOWN	C
PITTWOOD	B
PITZER	C
PIUTE	D
PLACEDO	D
PLACENTIA	D

PLACERITOS	C
PLACID	A/D
PLACK	D
PLAINFIELD	A
PLAINVIEW	C
PLAISTED	C
PLANO	B
PLASKETT	D
PLATA	B
PLATEA	C
PLATEAU	B
PLATNER	C
PLATO	C
PLATORO	B
PLATTE	D
PLATTVILLE	B
PLAZA	B/C
PLEASANT	C
PLEASANT GROVE	B
PLEASANTON	B
PLEASANT VALE	B
PLEASANT VIEW	B
PLEDGER	D
PLEEK	C
PLEINE	D
PLEVNA	D
PLOME	B
PLOVER	B
PLUMAS	B
PLUMMER	B/D
PLUSH	B
PLUTH	B
PLUTOS	C
PLYMOUTH	A
POALL	C
POARCH	B
POCALLA	A
POCATELLO	B
POCKER	D
POCOMOKE	D
PODO	D
PODUNK	B
POE	B/C
POEVILLE	D
POGAL	B
POGANEAB	D
POGUE	B
POHAKUPU	A
POINDEXTER	C
POINSETT	B
POINT	B
POINT ISABEL	C
POJOAQUE	B
POKEGEMA	B
POKEMAN	B
POKER	C
POLAND	B
POLAR	B
POLATIS	C
POLE	A
POLEBAR	C
POLELINE	B
POLEO	B
POLEY	C
POLICH	B
POLLARD	C
POLLASKY	C
POLLY	B
POLO	B
POLSON	C
POLVADERA	B
POMAT	C
POMELLO	C
POMPANO	A/D
POMPONIO	C/D
POMPTON	B
POMROY	B
PONCA	B
PONCENA	D
PONCHA	A
POND	B/C
POND CREEK	B
PONDILLA	A
PONIL	D
PONTOTOC	B
PONZER	D
POOKU	A
POOLE	B/D
POOLER	D
POORMA	B
POPE	B
POPPLETON	A
POQUONOCK	C
PORRETT	B/D
PORT	B
PORTAGEVILLE	D
PORTALES	B
PORTALTO	B
PORT BYRON	B
PORTERS	B
PORTERVILLE	D
PORTHILL	C
PORTINO	C
PORTLAND	D
PORTNEUF	B
PROTOLA	C
PORTSMOUTH	D
PORUM	C
POSANT	C
POSEY	B
POSITAS	D
POSKIN	C
POSOS	C
POSE	D
POTAMO	D
POTH	C
POTLATCH	C
POTRATZ	C
POTSDAM	B
POTTER	C
POTTS	B
POUDRE	B
POULTNEY	B
POUNCEY	D
POVERTY	A
POWDER	B
POWDERHORN	C
POWELL	C
POWER	B
POWHITE	C
POWLEY	D
POWWATKA	C
POY	D
POYGAN	D
POZO	C/D
POZO BLANCO	B
PRAG	C
PRATHER	B
PRATLEY	C
PRATT	A
PREACHER	B
PREAKNESS	D
PREBISH	D
PREBLE	C
PRENTISS	C
PRESQUE ISLE	B
PRESTO	A
PRESTON	A
PREWITT	B
PREY	D
PRICE	C
PRIDA	D
PRIDHAM	D
PRIETA	D
PRIMEAUX	C
PRINGHAR	B
PRINCETON	B
PRINEVILLE	C
PRING	B
PRINS	C
PRITCHETT	C
PROCTOR	B
PROGRESSO	C
PROMISE	D
PROMO	D
PROMONTORY	B
PRONG	C
PROSPECT	B
PROSPER	B
PROSSER	C
PROTIVIN	C
PROUT	C
PROVIDENCE	C
PROVO	D
PROVO BAY	D
PROWERS	B
PTARMIGAN	B
PUAULU	A
PUCHYAN	A
PUDDLE	D
PUERCO	D
PUERTA	D
PUETT	D
PUGET	B/C
PUGSLEY	B
PUHI	A
PUHIMAU	D
PULASKI	B
PULEHU	B
PULLMAN	D
PULS	D
PULSIPHER	D
PULTNEY	C
PUMEL	C
PUMPER	C
PUNA	A
PUNALUU	D
PUNOHU	A
PURDAM	C
PURDY	D
PURGATORY	D
PURNER	D
PURSLEY	B
PURVES	D
PUSTOI	A
PUTNAM	D
PUUKALA	D
PUUONE	C
PUU OO	A
PUU OPAE	B
PUU PA	B
PUYALLUP	B
PYLE	A
PYLON	D
PYOTE	A
PYRAMID	D
PYRMONT	D
QUACKENBUSH	C
QUAKER	C
QUAKERTOWN	B
QUANBA	D
QUAMON	A
QUANAH	B
QUANDAHL	B
QUARLES	D
QUARTZBURG	C
QUATAMA	C
QUAY	B
QUAZO	D
QUEALY	D
QUEBRADA	C
QUEENY	D
QUEETS	B
QUEMADO	C
QUENZER	D
QUICKSELL	D
QUIETUS	C
QUIGLEY	B
QUILCENE	C
QUILLLAYUTE	B
QUIMBY	B
QUINCY	A
QUINLAN	C
QUINN	D
QUINNEY	C
QUINTON	
QUITMAN	C
QUONSET	A
RABER	C
RABEY	A
RABIDEUX	B
RABUN	B
RACE	D
RACHERT	D
RACINE	B
RACOON	D
RAD	C
RADERSBURG	B
RADFORD	B
RADLEY	C
RADNOR	D
RAFAEL	D
RAGER	B
RAGLAN	C
RAGNAR	B
RAGO	C
RAGSDALE	B/D
RAGTOWN	D
RAHAL	C
RAHM	C
RAIL	C/D
RAINBOW	C
RAINEY	B
RAINS	B/D
RAINSBORO	C
RAKE	D
RALSEN	B/C
RAMADA	C
RAMADERO	B
RAMBLER	B
RAMELLI	C
RAMIRES	D
RAMMEL	C
RAMO	C
RAMONA	B
RAMPART	B
RAMPARTAR	A
RAMPARTER	A
RAMSEY	D
RAMSHORN	B
RANCE	C
RANCHERIA	B
RAND	B
RANDADO	C
RANDALL	D
RANDMAN	D
RANDOLPH	D
RANDS	C
RANGER	D
RANIER	C
RANKIN	C
RANTOUL	D
RANYHAN	B
RAPELJE	C
RAPHO	B
RAPIDAN	B
RAPLEE	C
RARDEN	C
RARICK	B
RARITAN	C
RASBAND	B
RASSET	B
RATAKE	C
RATHBUN	C
RATLIFF	B
RATON	D
RATTLER	B
RATTO	D
RAUB	B
RAUVILLE	D
RAUZI	B
RAVALLI	C
RAVENDALE	D
RAVENNA	C
RAVOLA	B
RAWAH	B
RAWHIDE	D
RAWSON	B
RAY	B
RAYADO	C
RAYENOUF	B
RAYMONDVILLE	D
RAYNE	B
RAYNESFORD	B
RAYNHAM	C
RAYNOR	D
RAZOR	C
RAZORT	B
READING	C
READINGTON	C
READLYN	B

REAGAN	B
REAKOR	B
REAL	C
REAP	D
REARDAN	C
REAVILLE	C
REBA	C
REBEL	B
REBUCK	
RECAL	D
RECLUSE	C
REDBANK	B
RED BAY	B
RED BLUFF	C
RED BUTTE	B
REDBY	C
REDCHIEF	C
REDCLOUD	B
REDDICK	C
REDDING	D
REDFIELD	B
RED HILL	C
RED HOOK	C
REDLAKE	D
REDLANDS	B
REDLODGE	D
REDMANSON	B
REDMOND	C
REDNUN	C
REDOLA	B
REDONA	B
REDRIDGE	B
REDROB	D
RED ROCK	B
RED SPUR	B
REDSTOE	B
REDTHAYNE	B
REDTOM	C
REDVALE	C
REDVIEW	C
REE	B
REEBEX	C
REED	D
REEDER	B
REEDPOINT	C
REEDY	D
REELFOOT	C
REESER	C
REESVILLE	C
REEVES	C
REFUGE	C
REGAN	B
REGENT	C
REHM	C
REICHEL	B
REIFF	B
REILLY	A
REINACH	B
REKOP	D
RELAN	A
RELAY	B
RELIANCE	C
RELIZ	D
RELSE	B
REMBERT	D
REMMIT	A
REMSEN	D
REMUDAR	B
REMUNDA	C
RENBAC	D
RENCALSON	C
RENCOT	A
RENFROW	D
RENICK	D
RENNIE	C/D
RENO	D
RENOHILL	C
RENOVA	D
RENOX	B
RENSHAW	B
RENSLOW	B
RENSSELAER	C
RENTIDE	C
RENTON	B/C
RENTSAC	C
REPARADA	D
REPP	A
REPPART	B
REPUBLIC	B
RESCUE	C
RESERVE	B
RESNER	B
RET	B/C
RETRIEVER	D
RETSOF	C
RETSOK	B
REXBURG	B
REXFORD	C
REXOR	A
REYES	C/D
REYNOLDS	
REYNOSA	B
REYWAT	D
RHAME	B
RHEA	B
RHINEBECK	D
RHOADES	D
RHOAME	C
RIB	C
RICCO	D
RICETON	B
RICEVILLE	C
RICHARDSON	B
RICHEAU	C
RICHEY	C
RICHFIELD	C
RICHFORD	A
RICHLIE	A
RICHMOND	D
RICHTER	B
RICHVALE	B
RICHVIEW	C
RICHWOOD	B
RICKMORE	C
RICKS	A
RICO	C
RICREST	B
RIDD	C
RIDGEBURY	C
RIDGECREST	C
RIDGEDALE	B
RIDGELAND	D
RIDGELAWN	A
RIDGELY	B
RIDGEVILLE	B
RIDGEWAY	D
RIDIT	C
RIETBROCK	C
RIFFE	B
RIFLE	A/D
RIGA	D
RIGGINS	A
RIGLEY	B
RILEY	C
RILLA	B
RILLITO	B
RIMEI	C
RIMINI	A
RIMROCK	D
RIN	B
RINCON	C
RINCONADA	C
RINDGE	D
RINGLING	C
RINGO	D
RINGOLD	B
RINGWOOD	B
RIO	D
RIO ARRIBA	D
RIOCONCHO	C
RIO GRANDE	B
RIO KING	C
RIO LAJAS	A
RIO PIEDRAS	B
RIPLEY	B
RIPON	B
RIRIE	B
RISBECK	B
RISLEY	D
RISTA	C
RISUE	D
RITCHEY	B
RITNER	C
RITO	B
RITTER	B
RITTMAN	C
RITZ	B/D
RITZCAL	B
RITZVILLE	B
RIVERHEAD	B
RIVERSIDE	A
RIVERTON	C
RIVERVIEW	B
RIVRA	A
RIXIE	C
RIXON	C
RIZ	D
ROANOKE	D
ROBANA	B
ROBBINS	B
ROBBS	D
ROBERTS	D
ROBERTSDALE	C
ROBERTSVILLE	D
ROBIN	B
ROBINSON	D
ROBINSONVILLE	B
ROBLEDO	D
ROB ROY	C
ROBY	C
ROCA	D
ROCHE	C
ROCHELLE	C
ROCHEPORT	C
ROCKAWAY	C
ROCKCASTLE	D
ROCK CREEK	D
ROCKFORD	B
ROCKHOUSE	A
ROCKINGHAM	C/D
ROCKLIN	C/D
ROCKLY	D
ROCKPORT	C
ROCK RIVER	B
ROCKTON	B
ROCKWELL	B
ROCKWOOD	B
ROCKY FORD	B
RODDY	
RODMAN	A
ROE	B
ROEBUCK	D
ROELLEN	D
ROEMER	C
ROESIGER	B
ROGERT	D
ROHNERVILLE	B
ROHRERSVILLE	C
ROIC	D
ROKEBY	D
ROLETTE	C
ROLFE	C
ROLISS	D
ROLLA	C
ROLLII	D
ROLOFF	C
ROMBERG	B
ROMBO	C
ROMEO	C
ROMNEY	C
ROMULUS	D
ROND	C
RONNEBY	B
RONSON	B
ROOSE	B
ROOTEL	D
ROSACHI	C
ROSAMOND	B
ROSANE	C
ROSANKY	C
ROSARIO	C
ROSCOE	D
ROSCOMMON	D
ROSEBERRY	B/D
ROSEBLOOM	D
ROSEBUD	B
ROSEBURG	B
ROSE CREEK	C
ROSEGLEN	B
ROSEHILL	D
ROSELAND	D
ROSELLA	D
ROSELMS	D
ROSEMOUNT	B
ROSENDALE	B
ROSE VALLEY	C
ROSEVILLE	B
ROSEWORTH	C
ROSHE SPRINGS	D
ROSITAS	A
ROSLYN	B
ROSMAN	B
ROSNEY	C
ROSS	B
ROSE FORK	C
ROSSI	C
ROSSMOYNE	C
ROSS VALLEY	C
ROTAN	C
ROTHIEMAY	B
ROTHSAY	B
ROTTULEE	B
ROUBIDEAU	C
ROUEN	C
ROUND BUTTE	D
ROUNDLEY	C
ROUNDTOP	C
ROUNDUP	C
ROUNDY	C
ROUSSEAU	A
ROUTON	D
ROUTT	C
ROVAL	D
ROWE	D
ROWENA	C
ROWLAND	C
ROWLEY	B
ROXAL	D
ROXBURY	B
ROY	B
ROYAL	B
ROYALTON	C
ROYCE	B
ROYSTONE	B
ROZA	D
ROZELLVILLE	B
ROZETTA	B
ROZLEE	C
RUARK	C
RUBICON	A
RUBIO	C
RUBY	B
RUBYHILL	C
RUCH	B
RUCKLES	D
RUCLICK	C
RUDD	D
RUDEEN	B
RUDOLPH	C
RUDYARD	D
RUELLA	B
RUGGLES	B
RUIDOSO	C
RUKO	D
RULE	B
RULICK	C
RUMBO	C
RUMFORD	B
RUMNEY	C
RUMPLE	C
RUM RIVER	C
RUNE	C
RUNGE	B
RUNNELLS	C
RUNNYMEDE	B
RUPERT	A
RUSCO	C
RUSE	D
RUSH	C
RUSHTOWN	A
RUSHVILLE	D
RUSS	B
RUSSELL	B
RUSSELLVILLE	C
RUSSLER	C

RUSTON	B
RUTLAND	C
RUTLEGE	D
RYAN	D
RYAN PARK	B
RYDE	B/D
RYDER	C
RYEGATE	B
RYELL	A
RYEPATCH	D
RYER	C
RYORP	C
RYUS	C
SABANA	D
SABANA SECA	D
SABENYO	B
SABINA	C
SABINE	A
SABLE	D
SAC	B
SACO	D
SACRAMENTO	C/D
SACUL	D
SADDLE	B
SADDLEBACK	B
SADER	D
SADIE	B
SADLER	C
SAFFELL	B
SAGANING	D
SAGE	D
SAGEHILL	B
SAGEMOOR	C
SAGERTON	C
SAGINAW	
SAGO	D
SAGOUSPE	C
SAGUACHE	A
SAHALIE	B
SAINT HELENS	A
SAINT MARTIN	C
SALADO	B
SALADON	D
SALAL	B
SALAMATOF	D
SALAS	C
SALCHAKET	B
SALEM	B
SALEMSBURG	B
SALGA	C
SALIDA	A
SALINAS	C
SALISBURY	D
SALIX	B
SALKUM	C
SALLISAW	B
SALLYANN	C
SALMON	B
SALOL	D
SALONIE	D
SALREE	C/D
SALTAIR	D
SALT CHUCK	A
SALTER	B
SALTERY	D
SALT LAKE	D
SALUDA	C
SALUVIA	
SALVISA	C
SALZER	D
SAMBA	D
SAMISH	C/D
SAMMAMISH	C
SAMPSEL	D
SAMPSON	B
SAMSIL	D
SAN ANDREAS	C
SAN ANTON	B
SAN ANTONIO	C
SAN ARCACIO	B
SAN BENITO	B
SANCHEZ	D
SANDALL	C
SANDERSON	B
SANDLAKE	C
SANDLEE	A
SANELI	D
SAN EMIGDIO	B
SANFORD	A
SANGER	B
SAN GERMAN	D
SANGO	C
SANGREY	A
SANILAC	C
SAN ISABEL	B
SAN JOAQUIN	D
SAN JON	C
SAN JOSE	B
SAN JUAN	A
SAN LUIS	B
SAN MATEO	B
SAN MIGUEL	C
SANPETE	B
SANPITCH	C
SAN POIL	B
SAN SABA	D
SAN SEBASTIAN	B
SANTA	C
SANTA CLARA	C
SANTA FE	D
SANRTA ISABEL	D
SANTA LUCIA	C
SANTA MARTA	C
SANTANA	C
SANTAQUIN	A
SANTA YNEZ	C
SANTEE	D
SANTIAGO	B
SANTIAM	C
SAN TIMOTEO	C
SANTONI	D
SANTOS	C
SANTO TOMAS	B
SAN YSIDRO	D
SAPINERO	B
SAPP	D
SAPPHIRE	B
SAPPHO	B
SAPPINGTON	B
SARA	C
SARALEGUI	B
SARANAC	D
SARAPH	D
SARATOGA	B
SARATON	B
SARBEN	A
SARCO	B
SARDINIA	C
SARDO	B
SARGEANT	D
SARITA	A
SARKAR	D
SARPY	A
SARTELL	A
SASKA	B
SASPAMCO	B
SASSAFRAS	B
SASSER	B
SATANKA	C
SATANTA	B
SATELLITE	C
SATT	D
SATTLEY	B
SATTRE	B
SATURN	B
SATUS	B
SAUCIER	B
SAUDE	B
SAUGATUCK	C
SAUGUS	B
SAUK	B
SAULICH	D
SAUM	C
SAUNDERS	C
SAUVIE	C/D
SAUVOLA	C
SAVAGE	C
SAVANNAH	C
SAVENAC	C
SAVO	C
SAVOIA	B
SAWABE	D
SAWATCH	C
SAWCREEK	B
SAWMILL	C
SAWYER	C
SAXBY	D
SAXON	B
SAYBROOK	B
SAYLESVILLE	C
SAYLOR	A
SCALA	B
SCAMMAN	C
SCANDIA	B
SCANTIC	C
SCAR	A
SCARBORO	D
SCAVE	C
SCHAFFENAKER	A
SCHAMBER	A
SCHAMP	C
SCHAPVILLE	C
SCHEBLY	D
SCHERRARD	D
SCHLEY	B
SCHMUTZ	B
SCHNEBLY	D
SCHNEIDER	C
SCHNOGRSON	B/D
SCHNORBUSH	C
SCHODACK	
SCHOOSON	C
SCHOFIELD	B
SCHOHARIE	C
SCHOLLE	B
SCHOOLEY	C/D
SCHOONER	D
SCHRADER	D
SCHRAP	D
SCHRIER	B
SCHROCK	B
SCHUMACHER	B
SCHUYLKILL	B
SCIO	B
SCIOTOVILLE	C
SCISM	B
SCITUATE	C
SCOBEY	C
SCOOTENEY	B
SCORUP	C
SCOTT	D
SCOTT LAKE	B
SCOUT	B
SCOWLALE	C
SCRANTON	B/D
SCRAVO	A
SCRIBA	C
SCRIVER	B
SCROGGIN	C
SCULLIN	C
SEABROOK	C
SEAMAN	C
SEAQUEST	C
SEARCHLIGHT	C
SEARING	B
SEARLA	B
SEARLES	C
SEATON	B
SEATTLE	D
SEAWILLOW	B
SEBAGO	D
SEBASTIAN	D
SEBASTOPOL	C
SEBEKA	D
SEBEWA	B/D
SEBREE	D
SEBRING	D
SEBUD	B
SECATA	C/D
SECCA	C
SECRET	C
SECRET CREEK	B
SEDAN	
SEDILLO	B
SEDWELL	C
SEEDSKADEE	D
SEES	C
SEEWEE	B
SEGAL	D
SEGNO	C
SEHORN	D
SEITZ	C
SEJITA	D
SEKIL	C
SEKIU	D
SELAH	C
SELDEN	C
SELEGNA	D
SELFRIDGE	C
SELKIRK	D
SELLE	B
SELLERS	A/D
SELMA	B
SEMIAHMOO	D
SEMIHMOO	D
SEMINARIO	D
SEMIX	C
SEN	B
SENECAVILLE	C
SEQUATCHIE	B
SEQUIM	A
SEQUIN	B
SEQUOIA	C
SERENE	D
SERNA	D
SEROCO	A
SERPA	C/D
SERVOSS	D
SESAME	C
SESPE	C
SESSIONS	C
SESSUM	D
SETTERS	C
SETTLEMEYER	D
SEVAL	D
SEVERN	B
SEVILLE	D
SEVY	C
SEWARD	B
SEWELL	B
SEXTON	D
SEYMOUR	C
SHAAK	D
SHADELAND	C
SHAFFER	A
SHAKAN	B
SHAKESPEARE	C
SHAKOPEE	C
SHALCAR	D
SHALET	D
SHAM	D
SHAMBO	B
SHAMEL	B
SHANAHAN	B
SHANDON	
SHANE	D
SHANO	B
SHANTA	B
SHAPLEIGH	C/D
SHARATIN	B
SHARKEY	D
SHARON	B
SHARPSBURG	B
SHARROTT	D
SHARVANA	C
SHASKIT	B/C
SHASTA	A
SHAVANO	B
SHAVER	B
SHAWA	B
SHAWANO	A
SHAWMUT	B
SHAY	D
SHEAR	C
SHECKLER	C
SHEDADO	B
SHEDD	C
SHEEGE	D
SHEEP CREEK	C
SHEEPHEAD	C
SHEEPROCK	A
SHEETIRON	B
SHEFFIELD	D
SHELBURNE	C

SHELBY	B
SHELBYVILLE	B
SHELDON	
SHELIKOF	D
SHELLABARGER	B
SHELLDRAKE	A
SHELLROCK	A
SHELMADINE	D
SHELOCTA	B
SHELTON	C
SHENA	C
SHENANDOAH	C
SHEP	B
SHEPPARD	A
SHERANDO	A
SHERAR	C
SHERBURNE	B
SHERIDAN	B
SHERLOCK	B
SHERM	D
SHERRYL	B
SHERWOOD	B
SHIBLE	B
SHIELDS	C
SHIPPER	B
SHILOH	C
SHINAKU	D
SHINGLE	D
SHINGLETOWN	C
SHINN	B
SHINROCK	C
SHIOCTON	B
SHIPLEY	C
SHIPROCK	B
SHIRAT	B
SHIRK	C
SHOALS	C
SHOEBAR	B
SHOEFFLER	B
SHONKIN	D
SHOOFLIN	C
SHOOK	A
SHOREWOOD	C
SHOREY	B
SHORN	B
SHORT CREEK	D
SHOSHONE	D
SHOTWELL	D
SHOUNS	B
SHOWALTER	C
SHOWLOW	C
SHREWSBURY	D
SHRINE	B
SHROE	D
SHROUTS	D
SHUBUTA	C
SHULE	B
SHULLSBURG	C
SHUMWAY	B
SHUPERT	C
SHUWAH	B
SI	B
SIBLEYVILLE	B
SIBYLEE	D
SICILY	B
SICKLESTEETS	C
SIDELL	B
SIEANCIA	B
SIEBER	A
SIELO	C
SIEROCLIFF	D
SIERRA	B
SIERRAVILLE	B
SIESTA	D
SIFTON	B
SIGNAL	C
SIGURD	B
SIKESTON	D
SILCOX	B
SILENT	D
SILER	B
SILERTON	B
SILI	D
SILSTID	A
SILVER	C
SILVERADO	C
SILVERBOW	D
SILVER CREEK	D
SILVERTON	C
SILVIES	D
SIMAS	C
SIMCOE	C
SIMEON	A
SIMMLER	D
SIMMONT	C
SIMNER	A
SIMON	C
SIMONA	D
SIMOTE	C
SIMPERS	B
SIMPSON	C
SIMS	D
SINAI	C
SINCLAIR	C
SINE	C
SINGLETREE	C
SINGSAAS	B
SINNIGAM	C
SINOMAX	B
SINTON	B
SINUK	D
SION	B
SIOUX	A
SIPPLE	A
SIRI	B
SISKIYOU	B
SISSETON	B
SISSON	B
SITES	C
SITKA	B
SIXMILE	B
SIZEMORE	B
SIZER	B
SKAGGS	B
SKAGIT	B/C
SKAHA	A
SKALAN	C
SKAMANIA	B
SKAMOKAWA	B
SKANEE	C
SKELLOCK	B
SKERRY	C
SKIDMORE	B
SKILLET	C
SKINNER	C
SKIYOU	C
SKOKOMISH	B/C
SKOOKUMCHUCK	B
SKUMHEGAN	B
SKULL CREEK	D
SKUMPAH	D
SKUTUM	C
SKYBERG	C
SKYHAVEN	D
SKYKOMISH	B
SKYLICK	C
SKYLINE	D
SKYWAY	B
SLAB	D
SLATE CREEK	C
SLAUGHTER	C
SLAVEN	D
SLAWSON	B
SLAYTON	D
SLEETH	C
SLETTEN	D
SLICKROCK	B
SLIGHTS	D
SLIGO	B
SLIKOK	D
SLIP	B
SLIPMAN	B/C
SLOAN	D
SLOCUM	B
SLODUC	C
SLOSS	C
SLUICE	B
SMARTS	B
SMITH CREEK	A
SMITHDALE	B
SMITHNECK	B
SMITHTON	D
SMOLAN	C
SMOOT	D
SNAG	B
SNAHOPISH	B
SNAKE	C
SNAKE HOLLOW	B
SNAKELUM	B
SNEAD	D
SNELL	C
SNELLING	B
SNOHOMISH	D
SNOQUALMIE	B
SNOW	B
SNOWDEN	C
SNOWLIN	B
SNOWVILLE	D
SNOWY	A
SOAKPAK	B
SOAP LAKE	B
SOBOBA	A
SOBRANTE	C
SODA LAKE	B
SODHOUSE	D
SODUS	C
SOELBERG	B
SOFIA	B
SOGN	D
SOGZIE	B
SOKOLOF	B
SOLANO	D
SOLDATNA	B
SOLDIER	C
SOL DUC	B
SOLDUC	B
SOLLEKS	C
SOLLER	D
SOLOMON	D
SOLONA	B
SOMBRERO	D
SOMERS	B
SOMERSET	D
SOMERVELL	B
SOMSEN	C
SONOITA	B
SONOMA	D
SONTAG	D
SOPER	B/C
SOQUEL	B
SORDO	C
SORF	C
SORRENTO	B
SORTER	B/D
SOSA	C
SOTELLA	C
SOTIM	B
SOUTHFORK	D
SOUTHGATE	D
SOUTHWICK	C
SPAA	D
SPACE CITY	A
SPADE	B
SPALDING	D
SPAN	D
SPANAWAY	B
SPANEL	D
SPARTA	A
SPEARFISH	B
SPEARMAN	C
SPEARVILLE	C
SPECK	D
SPECTER	D
SPEELYAI	C
SPEIGLE	B
SPENARD	D
SPENCER	B
SPENLO	B
SPERRY	C
SPICER	C
SPILLVILLE	B
SPINKS	A
SPIRES	D
SPIRIT	B
SPIRO	B
SPLENDORA	C
SPLITRO	D
SPOFFORD	C
SPOKANE	B
SPONSELLER	B
SPOON BUTTE	D
SPOONER	C
SPOTTSWOOD	B
SPRAGUE	B/C
SPRECKELS	C
SPRING	C/D
SPRING CREEK	C
SPRINGDALE	B
SPRINGER	B
SPRINGERVILLE	D
SPRINGFIELD	D
SPRINGMEYER	C
SPRINGTOWN	C
SPROUL	D
SPUR	B
SPURLOCK	B
SQUALICUM	B
SQUAW	B
SQUILLCHUCK	B
SQUIMER	B
SQUIRES	B
ST. ALBANS	B
ST. CHARLES	B
ST. CLAIR	D
ST. ELMO	A
ST. GEORGE	C
ST. HELENS	A
ST. IGNACE	C
ST. JOE	B/D
ST. JOHNS	B/D
ST. LUCIE	A
ST. MARTIN	C
ST. MARYS	B
ST. NICHOLAS	D
ST. PAUL	B
ST. THOMAS	D
STAATSBURG	
STABLER	B
STACY	B
STADY	B
STAFFORD	C
STAGECOACH	B
STAHL	C
STALEY	C
STAMBAUGH	B
STAMFORD	D
STAMPEDE	D
STAN	B
STANDISH	C/D
STANEY	D
STANFIELD	C
STANLEY	C
STANSBURY	D
STANTON	D
STAPLETON	B
STARBUCK	D
STARGO	B
STARICHKOF	D
STARKS	C
STARLEY	D
STARR	B
STASER	B
STATE	B
STATEN	D
STATLER	B
STAVE	D
STAYTRON	D
STEAMBOAT	D
STEARNS	D
STECUM	A
STEED	A
STEEDMAN	D
STEEKEE	C
STEELE	B
STEESE	C
STEFF	C
STEGALL	C
STEIGER	A
STEINAUER	B
STEINBECK	B
STEINMETZ	D
STEINSBURG	C
STEIWER	C
STELLAR	C
STEMILT	C

STENDAL	C
STEPHEN	C
STEPHENSBURG	B
STEPHENVILLE	B
STERLING	B
STERLINGTON	B
STETSON	B
STETTER	D
STEUBEN	B
STEVENS	B
STEVENSON	B
STEWART	D
STICKNEY	C
STIDHAM	A
STIGLER	C
STILLMAN	A
STILLWATER	D
STILSON	B
STIMSON	B/C
STINGAL	B
STINSON	C
STIRK	D
STIRUM	B
STISSING	C
STIVERSVILLE	B
STOCKBRIDGE	B
STOCKLAND	B
STOCKPEN	D
STOCKTON	D
STODICK	D
STOKES	D
STOMAR	C
STONER	B
STONEWALL	A
STONO	B/D
STONYFORD	D
STOOKEY	B
STORDEN	B
STORLA	B
STORMITT	B
STORM KING	D
STORY	C
STOSSEL	C
STOUGH	C
STOWELL	D
STOY	C
STRAIGHT	C
STRAIN	B
STRASBURG	C
STRATFORD	B
STRAUSS	C
STRAW	B
STRAWN	B
STREATOR	C
STROLE	B
STRONGHURST	B
STRONTIA	B
STROUPE	C
STRYKER	B
STUBBS	C
STUCKCREEK	B
STUKEL	D
STUKEY	B
STUMBLE	A
STUMPP	D
STUMP SPRINGS	B
STUNNER	B
STUTTGART	D
STUTZMAN	C
STUTZVILLE	B/C
SUBLETTE	B
SUDBURY	B
SUDDUTH	C
SUFFIELD	C
SUGARLOAF	B
SUISUN	D
SULA	B
SULLY	B
SULPHURA	D
SULTAN	B
SUMAS	B/C
SUMDUM	D
SUMMA	B
SUMMERFIELD	C
SUMMERS	B
SUMMERVILLE	C
SUMMIT	C
SUMMITVILLE	B
SUMTER	C
SUN	D
SUNBURST	C
SUNBURY	B
SUNCOOK	A
SUND	C
SUNDELL	C
SUNDERLAND	C/D
SUNDOWN	B
SUNFIELD	B
SUNNILAND	C
SUNNYHAY	D
SUNNYSIDE	B
SUNNYVALE	C
SUNRAY	B
SUNRISE	D
SUNSET	B
SUNSHINE	C
SUNSWEET	C
SUNUP	D
SUPAN	B
SUPERIOR	C
SUPERSTITION	A
SUPERVISOR	C
SUPPLEE	B
SUR	B
SURGEM	C
SURGH	B
SURPRISE	B
SURRENCY	B/D
SURVYA	C
SUSIE CREEK	D
SUSITNA	B
SUSQUEHANNA	D
SUTHER	C
SUTHERLIN	C
SUTLEW	B/C
SUTPHEN	D
SUTTLER	B
SUTTON	B
SVEA	B
SVERDRUP	B
SVOLD	C
SWAGER	C
SWAKANE	C
SWAN	C
SWANBOY	D
SWANNER	D
SWANSON	B
SWANTON	B/D
SWANTOWN	C
SWAPPS	C
SWARTSWOOD	C
SWARTZ	D
SWASEY	D
SWASTIKA	C
SWATARA	A
SWAUK	C
SWAWILLIA	A
SWEATMAN	C
SWEDE	B
SWEDEN	B
SWEEN	C
SWEENEY	B
SWEET	C
SWEETGRASS	B
SWEETWATER	D
SWENODA	B
SWIFTCREEK	B
SWIFTON	A
SWIMS	A
SWINGLER	C
SWINK	D
SWISOOD	D
SWITCHBACK	C
SWITZERLAND	B
SWOPE	C
SWYGERT	C
SYCAMORE	B/C
SYCAN	A
SYLACAUGA	B/D
SYLVAN	B
SYMERTON	B
SYNAREP	B
SYRACUSE	B
SYRENE	D
SYRETT	C
TABERNASH	B
TABIONA	B
TABLE MOUNTAIN	B
TABLER	D
TABOR	D
TACAN	B
TACOMA	D
TACOOSH	D
TAFT	C
TAGGERT	C
TAHOMA	B
TAHQUAMENON	D
TAHQUATS	C
TAINTOR	C
TAJO	C
TAKEUCHI	C
TAKILMA	B
TAKOTNA	B
TALAG	D
TALANTE	C
TALAPUS	B
TALBOTT	C
TALCOT	C
TALIHINA	D
TALKEETNA	C
TALLAC	B
TALLADEGA	C
TALLAPOOSA	C
TALLEYVILLE	B
TALLS	B
TALLULA	B
TALLY	B
TALMAGE	A
TALMO	B
TALOKA	D
TALPA	D
TAMA	B
TAMAHA	C
TAMALCO	D
TAMBA	C/D
TAMELY	
TAMMANY CREEK	B
TAMMANY RIDGE	B
TAMMS	C
TAMPICO	B
TANAMA	D
TANBERG	D
TANDY	C
TANEUM	C
TANEY	C
TANGAIR	C
TANNA	C
TANNER	C
TANSEM	B
TANTALUS	A
TANWAX	D
TAOPI	C
TAOS	D
TAPIA	C
TAPPEN	D
TARA	B
TARKIO	D
TARKLIN	C
TARPO	C
TARRANT	D
TARRETE	D
TARRYALL	B
TASCOSA	B
TASSEL	D
TATE	B
TATIYEE	C
TATU	C
TATUM	C
TAUNTON	C
TAVARES	A
TAWAS	A/D
TAWCAW	C
TAYLOR	C
TAYLOR CREEK	D
TAYLORSFLAT	D
TAYLORSVILLE	C
TAYSOM	B
TAZLINA	A
TEAL	D
TEALSON	C
TEALWHIT	C
TEANAWAY	C
TEAPO	B
TEAS	C
TEASDALE	B
TEBO	B
TECHICK	B
TECOLOTE	B
TECUMSAH	B
TEDROW	B
TEEL	B
TEHACHAPI	D
TEHAMA	C
TEJA	D
TEJON	B
TEKOA	C
TELA	B
TELEFONO	C
TELEPHONE	D
TELFER	A
TELFERNER	D
TELIDA	D
TELL	B
TELLER	B
TELLICO	B
TELLMAN	B
TELSTAD	B
TEMESCAL	D
TEMPLE	B/C
TEMVIK	B
TENABO	D
TENAHA	B
TENAS	C
TENCEE	D
TENERIFFE	C
TENEX	A
TENIBAC	B
TENINO	B
TENNO	D
TENORIO	B
TENOT	C
TENRAG	B
TENSAS	D
TENSED	C
TENSLEEP	B
TEOCULLI	B
TEPEE	D
TEPETE	B/D
TERBIES	C
TERESA	C
TERINO	D
TERMINAL	D
TEROUGE	D
TERRA CEIA	A/D
TERRAD	D
TERRERA	C
TERRETON	C
TERRIC	B
TERRY	B
TERWILLIGER	C
TESAJO	A
TESCOTT	C
TESUQUE	B
TETON	A
TETONIA	B
TETONKA	C
TETOTUM	C
TEW	B/D
TEX	B
TEXLINE	B
TEZUMA	C
THACKERY	B
THADER	C
THAGE	C
THANYON	A
THATCHER	B
THATUNA	C
THAYNE	B
THEBES	B
THEBO	D
THEDALUND	C
THENAS	C
THEO	C

THERESA	B
THERIOT	D
THERMAL	C
THERMOPOLIS	D
THESS	B
THETFORD	A
THIEL	A
THIOKOL	C
THOENY	D
THOMAS	D
THORNDALE	D
THORNDIKE	C/D
THORNOCK	D
THORNTON	D
THORNWOOD	B
THOROUGHFARE	B
THORP	C
THORR	B
THORREL	B
THOW	B
THREE MILE	D
THROCK	C
THUNDERBIRD	D
THURBER	C
THURLONI	C
THURLOW	C
THURMAN	A
THURMONT	B
THURSTON	B
TIAGOS	B
TIAK	C
TIBAN	B
TIBBITTS	B
TICA	D
TICE	C
TICHIGAN	C
TICHNOR	D
TICKAPOO	D
TICKASON	B
TIDWELL	D
TIERRA	D
TIETON	B
TIFFANY	C
TIFTON	B
TIGER CREEK	B
TIGERON	A
TIGIWON	B
TIGRETT	
TIGUA	D
TIJERAS	B
TILFORD	B
TILLEDA	B
TILLICUM	B
TILLMAN	C
TILMA	C
TILSIT	C
TILTON	B
TIMBERG	C
TIMBERLY	B
TIMBLIN	D
TIMENTWA	B
TIMKEN	D
TIMMERMAN	B
TIMMONS	B
TIMPAHUTE	D
TIMPANOGOS	B
TIMPER	D
TIMPOONEKE	B
TIMULA	B
TINA	C
TINDAHAY	A
TINE	A
TINGEY	B
TINSLEY	A
TINTON	A
TINYTOWN	B
TIOCANO	D
TIOGA	B
TIPPAH	C
TIPPECANOE	B
TIPPER	A
TIPPERARY	A
TIPPIPAH	D
TIPPO	C
TIPTON	B
TIPTONVILLE	B
TIRO	C
TISBURY	B
TISCH	C
TISH TANG	B
TITUSVILLE	C
TIVERTON	A
TIVOLI	A
TIVY	C
TOA	C
TOBICO	D
TOBIN	B
TOBISH	C
TOBLER	B
TOBOSA	D
TOBY	B
TOCCOA	B
TODD	B
TODDLER	B
TODDVILLE	B
TOEHEAD	C
TOEJA	C
TOEM	C
TOGO	B
TOGUS	D
TOHONA	C
TOINE	C
TOISNOT	D
TOIYABE	C
TOKEEN	B
TOKUL	C
TOLBY	A
TOLEDO	D
TOLICHA	D
TOLKE	B
TOLL	A
TOLLGATE	B
TOLLHOUSE	D
TOLMAN	D
TOLNA	B
TOLO	B
TOLSONA	D
TOLSTOI	D
TOLT	D
TOLTEC	C
TOLUCA	B
TOLVAR	B
TOMAH	C
TOMAS	B
TOMAST	C
TOME	B
TOMEL	D
TOMERA	D
TOMICHI	A
TOMOKA	A/D
TONASKET	B
TONATA	C
TONAWANDA	C
TONEY	D
TONGUE RIVER	C
TONINI	B
TONKA	C
TONKEY	D
TONKIN	C
TONKS	B/D
TONOPAH	B
TONOR	C
TONRA	A
TONSINA	B
TONUCO	C
TOOLE	D
TOOMES	C
TOP	C
TOPIA	D
TOPPENISH	B/C
TOPTON	
TOQUERVILLE	C
TOQUOP	A
TORBOY	B
TORCHLIGHT	C
TORDIA	D
TORHUNTA	C
TORNING	B
TORODA	B
TORONTO	C
TORPEDO LAKE	D
TORREON	C
TORRES	B
TORRINGTON	B
TORRO	C
TORSIDO	D
TORTUGAS	D
TOSTON	D
TOTELAKE	A
TOTEM	B
TOTTEN	B
TOUCHET	B
TOUHEY	B
TOULON	B
TOURN	C
TOURNQUIST	B
TOURS	B
TOUTLE	A
TOWER	D
TOWHEE	D
TOWNER	B
TOWNLEY	C
TOWNSBURY	B
TOWNSEND	C
TOWSON	B
TOXAWAY	D
TOY	D
TOYAH	B
TOZE	B
TRABUCO	C
TRACK	B/C
TRACY	B
TRAER	C
TRAIL	A
TRAIL CREEK	B
TRAM	B
TRANSYLVANIA	B
TRAPPER	A
TRAPPIST	C
TRAPPS	B
TRASK	C
TRAVELERS	D
TRAVER	B/C
TRAVESSILLA	D
TRAVIS	C
TRAWICK	B
TRAY	C
TREADWAY	D
TREASURE	B
TREBLOC	D
TREGO	C
TRELONA	D
TREMANT	B
TREMBLES	B
TREMPE	A
TREMPEALEAU	B
TRENARY	B
TRENT	B
TRENTON	D
TREP	B
TRES HERMANOS	B
TRETTEN	C
TREVINO	D
TREXLER	C
TRIAMI	C
TRIASSIC	
TRICON	C
TRIDELL	B
TRIDENT	D
TRIGO	C
TRIMBLE	B
TRIMMER	B
TRINCHERA	C
TRINITY	D
TRIOMAS	B
TRIPIT	C
TRIPLEN	B
TRIPOLI	C
TRIPP	B
TRITON	C
TRIX	B
TROJAN	B
TROMMALD	D
TROMP	C
TRONSEN	C
TROOK	B
TROPAL	D
TROSI	D
TROUP	A
TROUT CREEK	C
TROUTDALE	B
TROUT LAKE	C
TROUT RIVER	A
TROUTVILLE	B
TROXEL	B
TROY	C
TRUCE	C
TRUCKEE	C
TRUCKTON	B
TRUEFISSURE	A
TRUESDALE	C
TRULL	C
TRULON	B
TRUMAN	B
TRUMBULL	D
TRUMP	D
TRYON	D
TSCHICOMA	B
TUB	C
TUBAC	C
TUCANNON	C
TUCKERMAN	D
TUCSON	B
TUCUMCARI	B
TUFFIT	D
TUGHILL	D
TUJUNGA	A
TUKEY	C
TUKWILA	B
TULA	C
TULANA	C/D
TULARE	C/D
TULAROSA	B
TULIA	B
TULLAHASSEE	C
TULLER	D
TULLOCK	B
TULLY	C
TULUKSAK	D
TUMBEZ	D
TUMEY	D
TUMITAS	B
TUMWATER	A
TUNEHEAN	D
TUNICA	D
TUNIS	D
TUNITAS	B
TUNKHANNOCK	A
TUNNEL	B
TUPELO	D
TUPUKNUK	D
TUQUE	B
TURBEVILLE	C
TURBOTVILLE	C
TURBYFILL	B
TURIN	B
TURK	D
TURKEYSPRINGS	C
TURLEY	C
TURLIN	B
TURNBOW	C
TURNER	B
TURNERVILLE	B
TURNEY	B
TURRAH	D
TURRET	B
TURRIA	C
TURSON	B/C
TUSCAN	D
TUSCARAWAS	C
TUSCARORA	C
TUSCOLA	B
TUSCUMBIA	D
TUSEL	C
TUSKEEGO	C
TUSLER	B
TUSQUITEE	B
TUSTIN	B
TUSTUMENA	B
TUTHILL	B
TUTNI	B
TUTWILER	B
TUXEDO	
TUXEKAN	B
TWIN CREEK	B
TWINING	C
TWISP	B
TWO DOT	C

TYBO	D
TYEE	D
TYGART	D
TYLER	D
TYNDALL	B/C
TYNER	A
TYRONE	C
TYSON	C
UANA	D
UBAR	C
UBLY	B
UCOLA	D
UCOLO	C
UCOPIA	B
UDEL	D
UDOLPHO	C
UFFENS	D
UGAK	D
UHLAND	B
UHLIG	B
UINTA	B
UKIAH	C
ULEN	B
ULLOA	B
ULM	B
ULRICHER	B
ULUPALAKUA	B
ULY	B
ULYSSES	B
UMA	A
UMAPINE	B/C
UMIAT	D
UMIKOA	B
UMIL	D
UMNAK	B
UMPA	B
UMPQUA	B
UNA	D
UNADILLA	B
UNAWEEP	B
UNCOM	B
UNCOMPAHGRE	D
UNEEDA	B
UNGERS	B
UNION	C
UNIONTOWN	B
UNIONVILLE	C
UNISUN	C
UPDIKE	D
UPSAL	C
UPSATA	A
UPSHUR	C
UPTON	C
URACCA	B
URBANA	C
URBO	D
URICH	D
URNE	B
URSINE	D
URTAH	C
URWIL	D
USAL	B
USHAR	B
USINE	B
USKA	D
UTALINE	B
UTE	C
UTICA	A
UTLEY	B
UTUADO	B
UVADA	D
UVALDE	C
UWALA	B
VACHERIE	C
VADER	B
VADO	B
VAIDEN	D
VAILTON	B
VALBY	C
VALCO	C
VALDEZ	B/C
VALE	B
VALENCIA	B
VALENT	A
VALENTINE	A
VALERA	C
VALKARIA	B/D
VALLAN	D
VALLECITOS	C/D
VALLEONO	B
VALLERS	C
VALMONT	C
VALMY	B
VALOIS	B
VAMER	D
VANAJO	D
VANANDA	D
VAN BUREN	
VANCE	C
VANDA	D
VANDALIA	C
VANDERDASSON	D
VANDERGRIFT	C
VANDERHOFF	D
VANDERLIP	A
VAN DUSEN	B
VANET	D
VANG	B
VANHORN	B
VAN NOSTERN	B
VANNOY	B
VANOSS	B
VANTAGE	C
VAN WAGONER	D
VARCO	C
VARELUM	C
VARICK	D
VARINA	C
VARNA	C
VARRO	BV
VARYSBURG	B
VASHTI	C
VASQUEZ	B
VASSALBORO	D
VASSAR	B
VASTINE	C
VAUCLUSE	C
VAUGHNSVILLE	C
VAYAS	D
VEAL	B
VEAZIE	B
VEBAR	B
VECONT	D
VEGA	C
VAGA ALTA	C
VEGA BAJA	C
VEKOL	D
VELDA	B
VELMA	B
VELVA	B
VENA	C
VENANGO	C
VENATOR	D
VENETA	C
VENEZIA	D
VENICE	D
VENLO	D
VENUS	B
VERBOORT	D
VERDE	C
VERDEL	D
VERDELLA	D
VERDICO	D
VERDIGRIS	B
VERDUN	D
VERGENNES	D
VERHALEN	D
VERMEJO	D
VERNAL	B
VERNALIS	B
VERNIA	A
VERNON	D
VERONA	C
VESSER	C
VESTON	D
VETAL	A
VETERAN	B
VEYO	D
VIA	B
VIAN	B
VIBORAS	D
VIBORG	B
VICKERY	C
VICKSBURG	B
VICTOR	A
VICTORIA	D
VICTORY	B
VICU	D
VIDA	B
VIDRINE	C
VIEJA	D
VIENNA	B
VIEQUES	B
VIEW	C
VIGAR	C
VIGO	D
VIGUS	C
VIKING	D
VIL	D
VILAS	A
VILLA GROVE	B
VILLARS	B
VILLY	D
VINA	B
VINCENNES	C
VINCENT	C
VINEYARD	C
VINGO	B
VINING	C
VINITA	C
VINLAND	C
VINSAD	C
VINT	B
VINTON	B
VIRA	C
VIRATON	C
VIRDEN	C
VIRGIL	B
VIRGIN PEAK	D
VIRGIN RIVER	D
VIRTUE	C
VISALIA	B
VISTA	C
VIVES	B
VIVI	B
VLASATY	C
VOCA	C
VODERMAIER	B
VOLADORA	B
VOLCO	D
VOLENTE	C
VOLGA	D
VOLIN	B
VOLINIA	B
VOLKE	C
VOLKMAR	B
VOLMER	D
VOLNEY	B
VOLPERIE	C
VOLTAIRE	D
VOLUSIA	C
VONA	B
VORE	B
VROOMAN	B
VULCAN	C
VYLACH	D
WABANICA	D
WABASH	D
WABASHA	D
WABASSA	B/D
WABEK	B
WACA	C
WACOTA	B
WACOUSTA	C
WADAMS	B
WADDELL	B
WADDOUPS	B
WADELL	B
WADENA	B
WADESBORO	B
WADLEIGH	D
WADMALAW	D
WADSWORTH	C
WAGES	B
WAGNER	D
WAGRAM	A
WAHA	C
WAHEE	D
WAHIAWA	B
WAHIKULI	B
WAHKEENA	B
WAHKIACUS	B
WAHLUKE	B
WAHMONIE	D
WAHPETON	C
WAHTIGUP	C
WAHTUM	D
WAIAHA	D
WAIAKOA	C
WAIALEALE	D
WAIALUA	B
WAIAWA	D
WAIHUNA	D
WAIKALOA	B
WAIKANE	B
WAIKAPU	B
WAIKOHO	D
WAILUKU	B
WAIMEA	B
WAINEE	B
WAINOLA	A
WAIPAHU	C
WAISKA	B
WAITS	B
WAKE	D
WAKEEN	B
WAKEFIELD	B
WAKELAND	B/D
WAKONDA	C
WAKULLA	A
WALCOTT	B
WALDECK	C
WALDO	D
WALDRON	D
WALDROUP	D
WALES	B
WALFORD	C
WALKE	C
WALL	B
WALLACE	B
WALLA WALLA	B
WALLER	B/D
WALLINGTON	C
WALLIS	B
WALLKILL	C/D
WALLMAN	C
WALLOWA	C
WALLPACK	C
WALLROCK	B/C
WALLSBURG	D
WALLSON	B
WALPOLE	C
WALSH	B
WALSHVILLE	D
WALTERS	A
WALTON	C
WALUM	B
WALVAN	B
WAMBA	B/C
WAMIC	B
WAMPSVILLE	B
WANATAH	B
WANBLEE	D
WANDO	A
WANETTA	A
WANILLA	C
WANN	A
WAPAL	B
WAPATO	C/D
WAPELLO	B
WAPINITIA	B
WAPPING	B
WAPSIE	B
WARBA	B
WARD	D
WARDBORO	A
WARDELL	D
WARDEN	B
WARDWELL	C

WARE	B
WAREHAM	C
WARMAN	D
WARM SPRINGS	C
WARNERS	A/D
WARREN	
WARRENTON	B/D
WARRIOR	
WARSAW	B
WARSING	B
WARWICK	A
WASATCH	A
WASEPI	B
WASHBURN	
WASHINGTON	B
WASHOE	C
WASHOUGAL	B
WASHTENAW	C/D
WASHTENAW	C/D
WASILLA	D
WASIOJA	B
WASSAIC	B
WATAB	C
WATAUGA	B
WATCHAUG	B
WATCHUNG	D
WATERBORO	
WATERBURY	D
WATERINO	C
WATERS	C
WATKINS	B
WATKINS RIDGE	B
WATO	B
WATOPA	B
WATROUS	B
WATSEKA	C
WATSON	C
WATSONIA	D
WATSONVILLE	D
WATT	D
WATTON	C
WAUBAY	B
WAUBEEK	B
WAUBONSIE	B
WAUCHULA	B/D
WAUCOMA	B
WAUCONDA	B
WAUKEE	B
WAUKEGAN	B
WAUKENA	D
WAUKON	B
WAUMBEK	B
WAURIKA	D
WAUSEON	B/D
WAVERLY	B/D
WAWAKA	C
WAYCUP	B
WAYDEN	D
WAYLAND	C/D
WAYNE	B
WAYNESBORO	B
WAYSIDE	
WEA	B
WEAVER	C
WEBB	C
WEBER	B
WEBSTER	C
WEDEKIND	D
WEDERTZ	C
WEDGE	A
WEDOWEE	D
WEED	B
WEEDING	A/C
WEEDMARK	B
WEEKSVILLE	B/D
WEEPON	D
WEHADKEE	D
WEIKERT	C/D
WEIMER	D
WEINBACH	C
WEIR	D
WEIRMAN	B
WEISER	C
WEISHAUPT	D
WEISS	A
WEITCHPEC	B
WELAKA	A
WELBY	B
WELCH	C
WELD	C
WELDA	C
WELDON	D
WELDONA	B
WELLER	C
WELLINGTON	D
WELLMAN	B
WELLNER	B
WELLSBORO	C
WELLSTON	B
WELLSVILLE	B
WELRING	D
WEMPLE	B
WENAS	B/C
WENATCHEE	C
WENDEL	B/C
WENHAM	
WENONA	C
WENTWORTH	B
WERLOW	C
WERNER	B
WESO	C
WESSEL	B
WESTBROOK	D
WESTBURY	C
WESTCREEK	B
WESTERVILLE	C
WESTFALL	C
WESTFIELD	
WESTFORD	
WESTLAND	B/D
WESTMINSTER	C/D
WESTMORE	B
WESTMORELAND	B
WESTON	D
WESTPHALIA	B
WESTPLAIN	C
WESTPORT	A
WESTVILLE	B
WETHERSFIELD	C
WETHEY	B/C
WETTERHORN	C
WETZEL	D
WEYMOUTH	B
WHAKANA	B
WHALAN	B
WHARTON	C
WHATCOM	C
WHATELY	D
WHEATLEY	D
WHEATRIDGE	C
WHEATVILLE	B
WHEELER	B
WHEELING	B
WHEELON	D
WHELCHEL	B
WHETSTONE	B
WHIDBEY	C
WHIPPANY	C
WHIPSTOCK	C
WHIRLO	B
WHIT	B
WHITAKER	C
WHITCOMB	C
WHITE BIRD	C
WHITECAP	D
WHITEFISH	B
WHITEFORD	B
WHITEHORSE	B
WHITE HOUSE	C
WHITELAKE	B
WHITELAW	B
WHITEMAN	D
WHITEROCK	D
WHITESBURG	C
WHITE STORE	D
WHITE SWAN	C
WHITEWATER	B
WHITEWOOD	C
WHITLEY	B
WHITLOCK	B
WHITMAN	D
WHITNEY	B
WHITORE	A
WHITSOL	B
WHITSON	D
WHITWELL	C
WHOLAN	C
WIBAUX	C
WICHITA	C
WICHUP	D
WICKERSHAM	B
WICKETT	C
WICKHAM	B
WICKIUP	C
WICKLIFFE	D
WICKSBURG	B
WIDTSOE	C
WIEHL	C
WIEN	D
WIGGLETON	B
WIGTON	A
WILBRAHAM	C
WILBUR	C
WILCO	C
WILCOX	D
WILCOXSON	C
WILDCAT	D
WILDER	B
WILDERNESS	C
WILDROSE	D
WILDWOOD	D
WILEY	C
WILKES	C
WILKESON	C
WILKINS	D
WILL	D
WILLACY	B
WILLAKENZIE	C
WILLAMAR	D
WILLAMETTE	B
WILLAPA	C
WILLARD	B
WILLETTE	A/D
WILLHAND	B
WILLIAMS	B
WILLIAMSBURG	B
WILLIAMSON	C
WILLIS	C
WILLITS	B
WILLOUGHBY	B
WILLOW CREEK	B
WILLOWDALE	B
WILLOWS	D
WILLWOOD	A
WILMER	C
WILPAR	D
WILSON	D
WILTSHIRE	C
WINANS	B/C
WINBERRY	D
WINCHESTER	A
WINCHUCK	C
WINDER	B/D
WINDHAM	B
WINDMILL	B
WINDOM	B
WIND RIVER	B
WINDSOR	A
WINDTHORST	C
WINDY	C
WINEG	C
WINEMA	C
WINETTI	B
WINFIELD	C
WING	D
WINGATE	B
WINGER	C
WINGVILLE	B/D
WINIFRED	C
WINK	B
WINKEL	D
WINKLEMAN	C
WINKLER	A
WINLO	D
WINLOCK	C
WINN	C
WINNEBAGO	B
WINNEMUCCA	B
WINNESHIEK	B
WINNETT	D
WINONA	D
WINOOSKI	B
WINSTON	A
WINTERS	C
WINTERSBURG	C
WINTERSET	C
WINTHROP	A
WINTONER	C
WINU	C
WINZ	C
WIOTA	B
WISHARD	A
WISHEYLU	C
WISHKAH	C
WISKAH	C
WISNER	D
WITBECK	D
WITCH	D
WITHAM	D
WITHEE	C
WITT	B
WITZEL	D
WODEN	B
WODSKOW	B/C
WOLCOTTSBURG	
WOLDALE	C/D
WOLF	B
WOLFESEN	C
WOLFESON	C
WOLFORD	B
WOLF POINT	D
WOLFTEVER	C
WOLVERINE	A
WOODBINE	B
WOODBRIDGE	C
WOODBURN	C
WOODBURY	D
WOODCOCK	B
WOODENVILLE	C
WOODGLEN	D
WOODHALL	B
WOODHURST	A
WODDINVILLE	C/D
WOODLY	B
WOODLYN	C/D
WOODMANSIE	B
WOODMERE	B
WOOD RIVER	D
WOODROCK	C
WOODROW	C
WOODSCROSS	D
WOODSFIELD	C
WOODSIDE	A
WOODSON	D
WOODSTOCK	C/D
WOODSTOWN	C
WOODWARD	B
WOOLMAN	B
WOOLPER	C
WOOLSEY	C
WOOSLEY	C
WOOSTER	C
WOOSTERN	B
WOOTEN	A
WORCESTER	B
WORF	D
WORK	C
WORLAND	B
WORLEY	C
WORMSER	C
WOROCK	B
WORSHAM	D
WORTH	C
WORTHEN	B
WORTHING	D
WORTHINGTON	C
WORTMAN	C
WRENTHAM	C
WRIGHT	C
WRIGHTMAN	C
WRIGHTSVILLE	D
WUNJEY	B
WURTSBORO	C
WYALUSING	D
WYARD	B
WYARNO	B
WYATT	C
WYEAST	C
WYEVILLE	C

SYGANT	C
WYKOFF	B
WYMAN	B
WYMORE	C
WYNN	B
WYNOOSE	D
WYO	B
WYOCENA	B
XAVIER	B
YACOLT	B
YAHARA	B
YAHOLA	B
YAKI	D
YAKIMA	B
YAKUS	D
YALLANI	B
YALMER	B
YAMAC	B
YAMHILL	C
YAMPA	C
YAMSAY	D
YANA	B
YANCY	C
YARDLEY	C
YATES	D
YAUCO	C
YAWDIM	D
YAWKEY	C
YAXON	B
YEARY	C
YEATES HOLLOW	C
YEGEN	B
YELM	B
YENRAB	A
YEOMAN	B
YESUM	B
YETULL	A
YODER	B
YOKOHL	D
YOLLABOLLY	D
YOLO	B
YOLOGO	D
YOMBA	C
YOMONT	B
YONCALLA	C
YONGES	D
YONNA	B/D
YORDY	B
YORK	C
YORKVILLE	D
YOST	C
YOUGA	B
YOUMAN	C
YOUNGSTON	B
YOURAME	A
YOVIMPA	D
YSIDORA	D
YTRURBIDE	A
YUBA	D
YUKO	C
YUKON	D
YUNES	D
YUNQUE	C
ZAAR	D
ZACA	D
ZACHARIAS	B
ZACHARY	D
ZAFRA	B
ZAHILL	B
ZAHL	B
ZALESKI	C
ZALLA	A
ZAMORA	B
ZANE	C
ZANEIS	B
ZANESVILLE	C
ZANONE	C
ZAPATA	C
ZAVALA	B
ZAVCO	C
ZEB	B
ZEESIX	C
ZELL	B
ZEN	C
ZENDA	C
ZENIA	B
ZENIFF	B
ZEONA	A
ZIEGLER	C
ZIGWEID	B
ZILLAH	B/C
ZIM	D
ZIMMERMAN	A
ZING	C
ZINZER	B
ZION	C
ZIPP	C/D
ZITA	B
ZOAR	C
ZOATE	D
ZOHNER	B/D
ZOOK	C
ZORRAVISTA	A
ZUFELT	B/D
ZUKAN	D
ZUMBRO	B
ZUMWALT	C
ZUNDELL	B/C
ZUNHALL	B/C
ZUNI	D
ZURICH	B
ZWINGLE	D

APPENDIX E

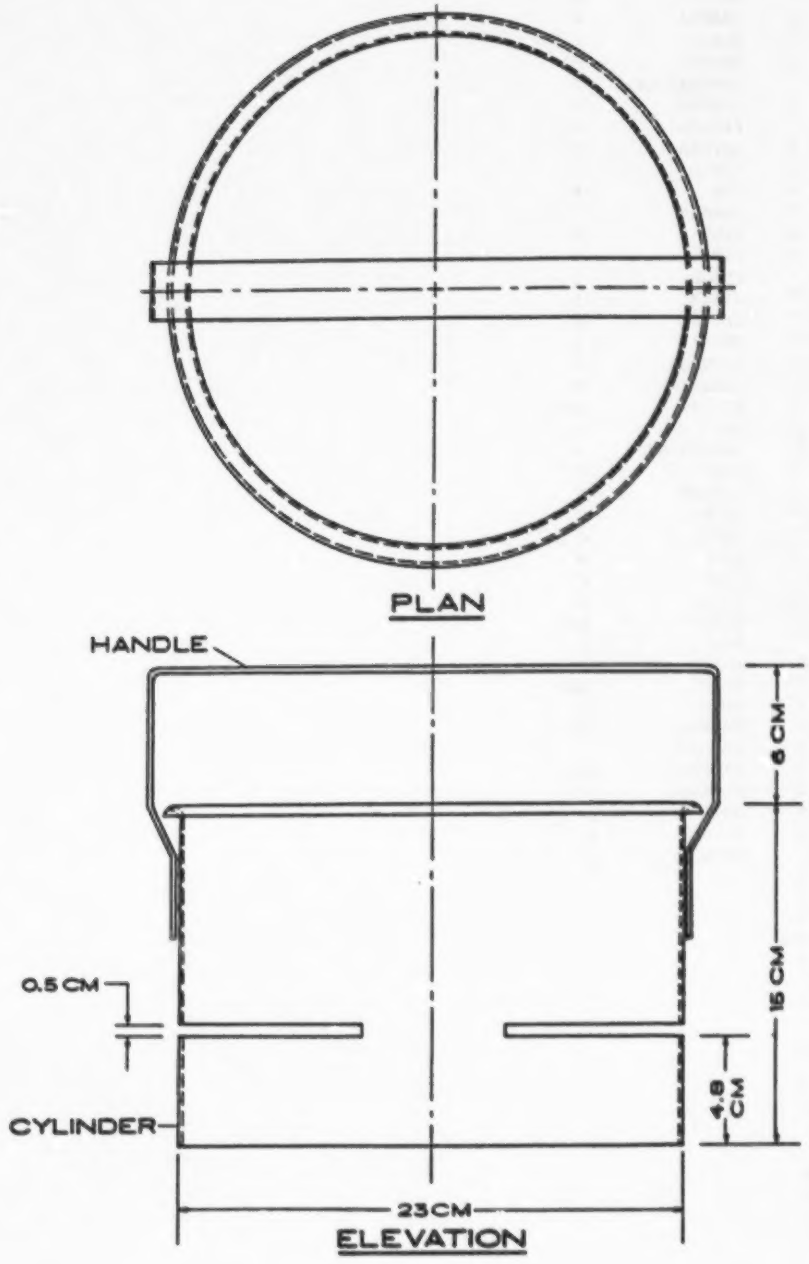
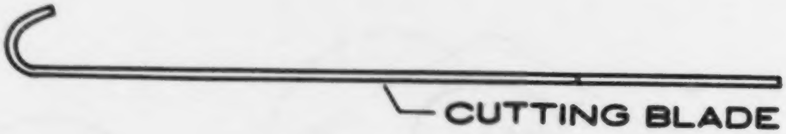
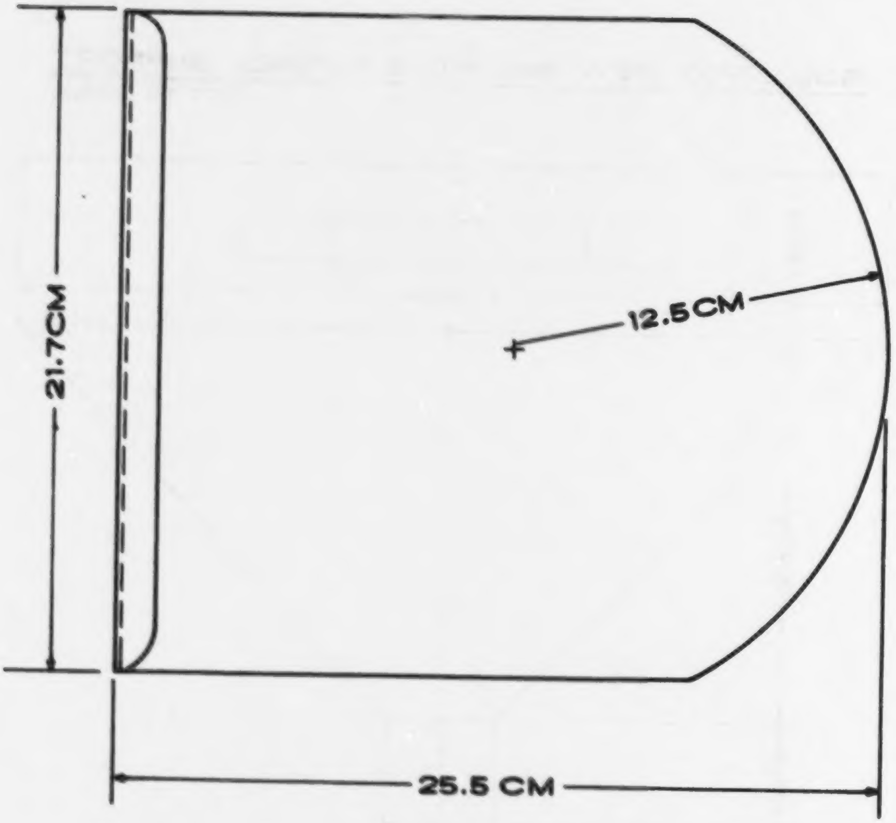

PLAN
HANDLE
6 CM
15 CM
0.5 CM
4.8 CM
CYLINDER
23CM
ELEVATION

FIGURE E.1. Surface soil sampler design with transfer funnel specifications.

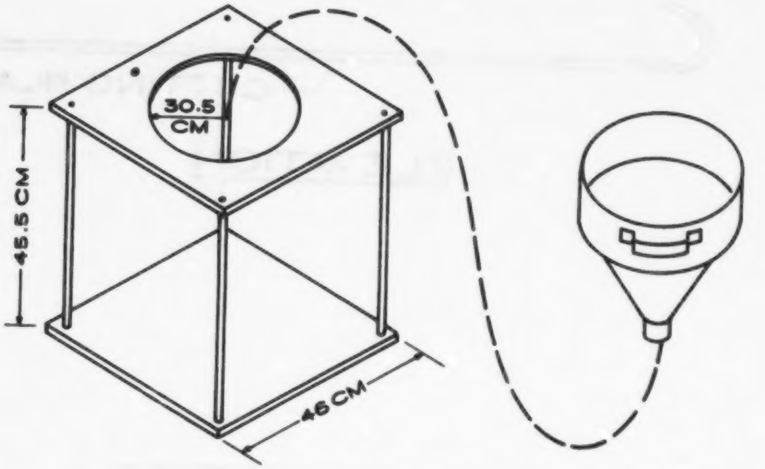

CUTTING BLADE

ELEVATION


21.7CM
12.5CM
25.5 CM

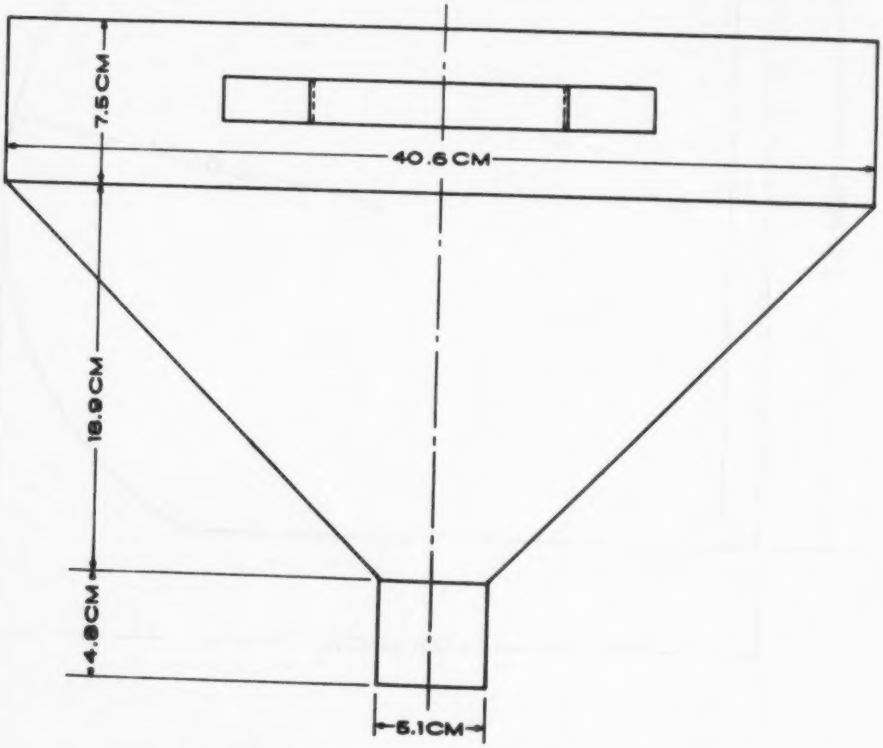
PLAN

FIGURE E.1 (Cont'd). Surface soil sampler design with transfer funnel specifications.


30.5
CM
45.5 CM
46 CM

ISOMETRIC VIEW SHOWING FUNNEL SUPPORT

NOT TO SCALE


7.5CM
40.6CM
18.9CM
4.8CM
5.1CM

FUNNEL - ELEVATION VIEW

FIGURE E.1 (Cont'd). Surface soil sampler design with transfer funnel specifications.

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